GENERAL ELECTRIC

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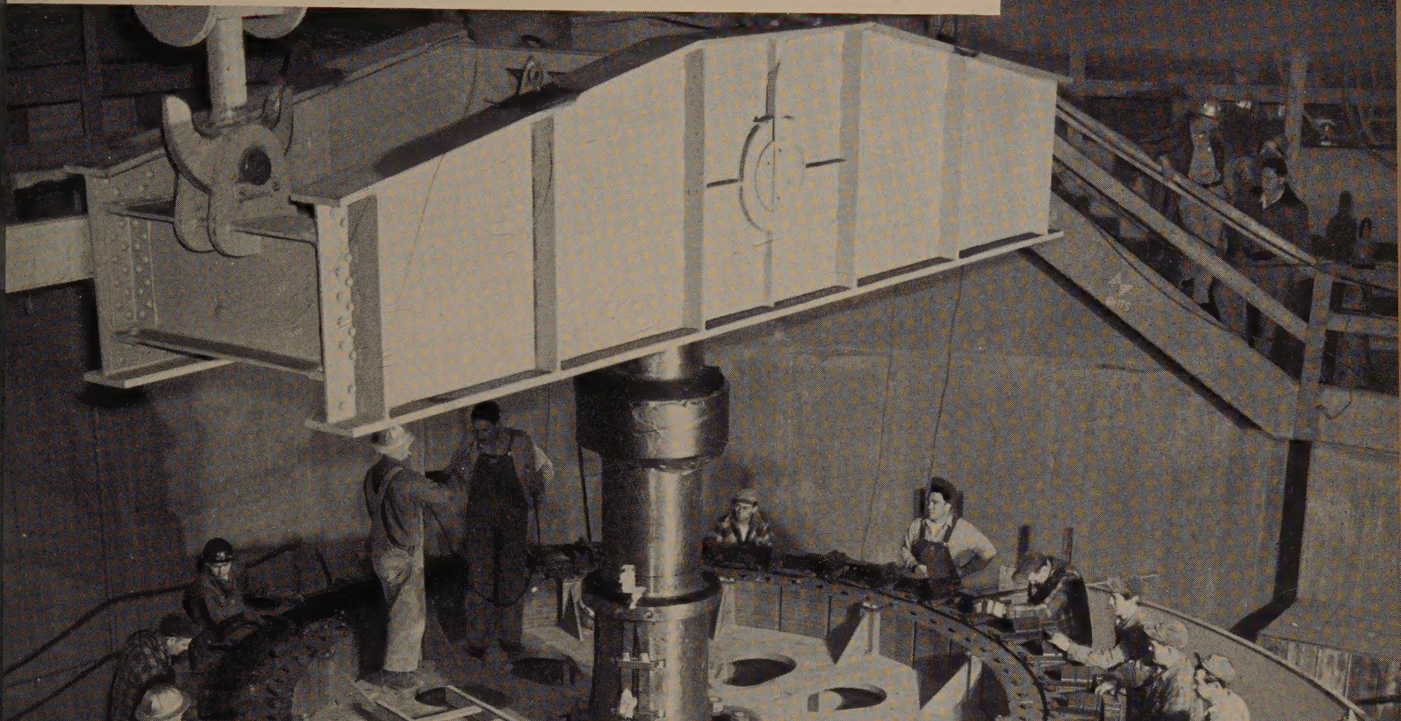
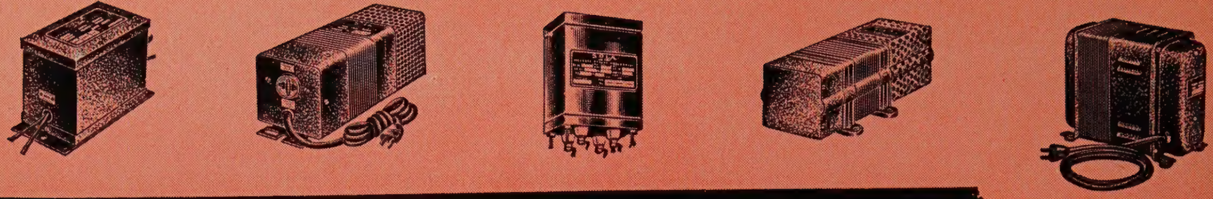


RECISION GUIDANCE

May 1951

VOL. 54 NO. 5



SOLA voltage regulation *for Military Components*

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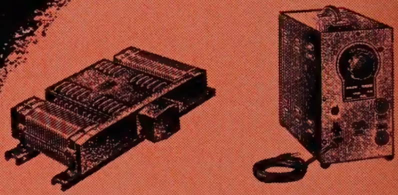
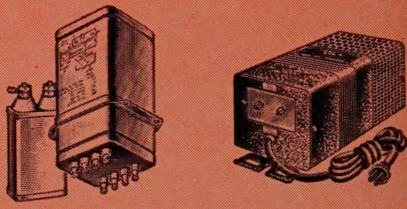


OF THE MANY REGULATING



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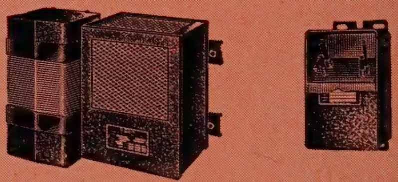

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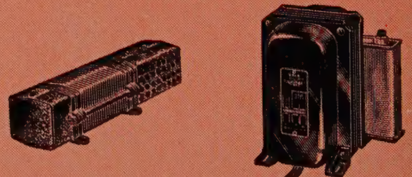

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GENERAL ELECTRIC Review

MAY, 1951
Vol. 54, No. 5

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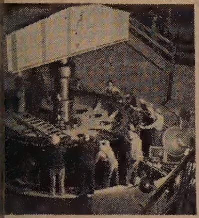

THE COVER

g the 170-ton rotating field in the first Electric Company 65,000-hp 200-rpm olt 3-phase 60-cycle motor at Grand Coulee Plant for the U.S. Bureau of Reclamation State of Washington. These motors are d with General Electric thrust bearings ar-or oil-pressure starting and will lift water ver a mountain to a reservoir from which ousands of acres of semiarid land will be l. (*See page 39.*)

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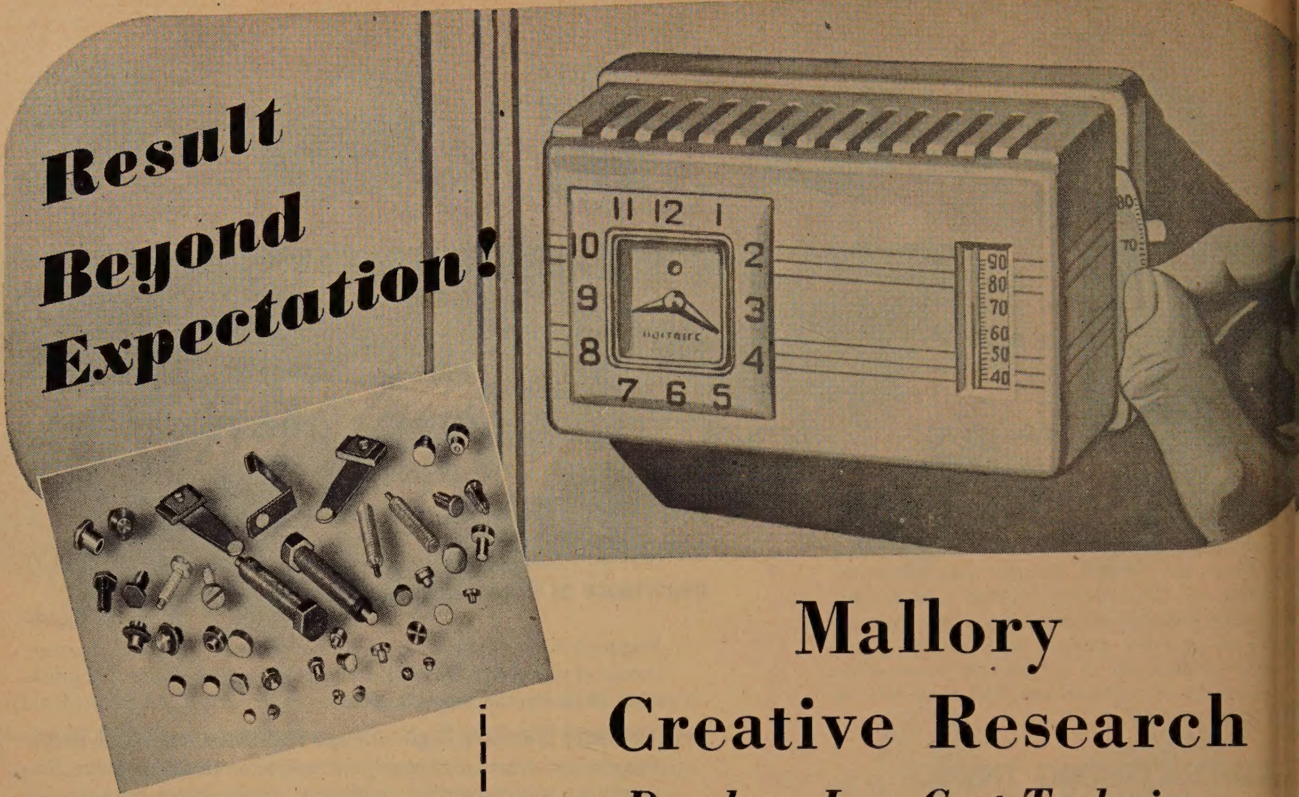
Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under Act of March 3, 1879. Published monthly by General Electric Company, 1 River Road, Schenectady 5, N. Y. Printed in U. S. A. *Copyright 1951 by General Electric Company.*



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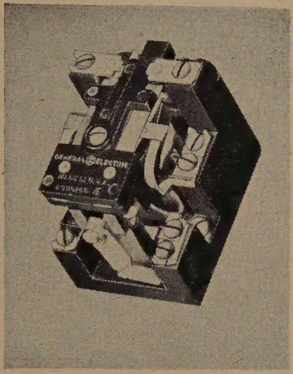

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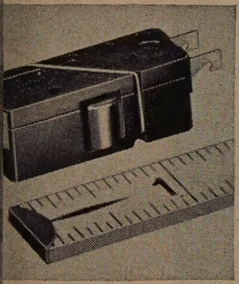

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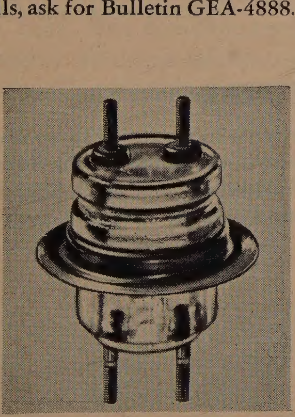

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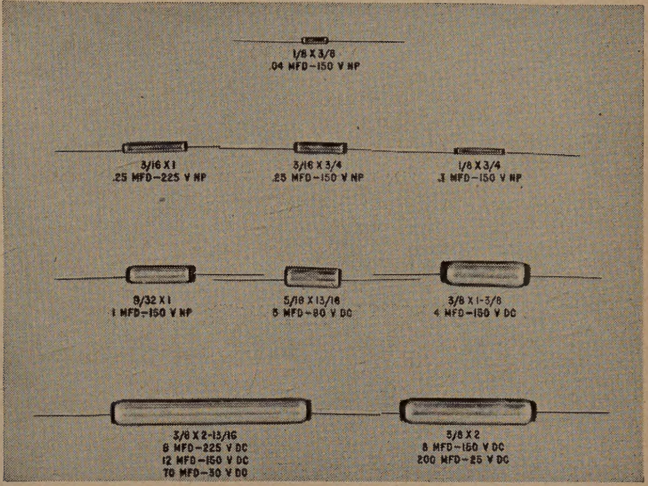

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GENERAL ELECTRIC Review

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MAY
1951

THE GREATEST OF WONDERS

HE greatest of wonders when placed in our hands for use and enjoyment are eagerly accepted. lve million television sets in five years—and in the k of this writing, untold millions of people stayed d to their television sets to follow the hearings of nited States Senate Crime Investigating Com- ee so that even the Easter bonnet trade was ted. And one of the greatest of electronic wonders ience and engineering came even more intimately the lives of men.

et hardly a person in that enormous audience ably realized the wonder of the achievement which bringing to him something he never had experienced re. Probably no one was thinking of the wonder of television camera tube which formed an image hat he was to see, transforming it into electric als to be transmitted by circuit and propagated ugh the atmosphere to be received by another uit, and transformed again from electric signals to mage on the tube he was seeing. All this in a tion of a thousandth of a second, an operation too plicated for comprehension and understanding pt by those who had studied and worked for its mplishment. And the study and the work behind accomplishment went back in years and included arch in the laboratories of our industries and of our neering schools.

ow the New York *Herald Tribune* for Sunday, ch 25, 1951, carried a note of the greatest of rest and significance. It said:

> ***"TV Ate Electricity***
>
> "So many television sets in New York were turned on for the Senate Crime Investigation Committee hearings that the Consolidated Edison Co. had to employ an extra generator—a big one capable of serving 80,000 homes—for daytime service.
>
> "The Con Ed said it would have had to throw even more reserve power into the system but for the fact that a number of vacuum cleaners, washing machines and irons apparently were left idle."

hat note tied together two great wonders of our and of our electrical industry—television and tric power—for as great as is the wonder of tele- n, equally as great is the wonder of electric power. o one closing an electric switch, particularly in home, probably realizes or even thinks to realize the wonders of electric power generation, transmission, and distribution, together with all the engineering advances—advances to bring a meaning to system stability; to protect against the ravages of lightning; to provide for the protection of equipment from damage due to faults and to prevent the faults; to provide for precision of control and for load dispatching to assure continuity of service; to provide for advances in design of equipment to more efficiently handle greater loads; and in every way to make the service of electricity so useful that it too is one of the greatest of wonders. And these accomplishments have come largely from the scientists and the engineers of the electrical industry working together.

These outstanding engineering advances have placed upon the teachers in our engineering schools the greatest of responsibility. In electronics there has been practically universal advance, with graduate work undergirded by research reflecting back to advantage into the undergraduate courses. In power systems engineering, however, the opportunity for research is limited because the components are large and costly and a long time is required for appraisal of the results. Here the teacher thus has a great handicap to overcome, and where he has overcome, it is by the sheer power of his enthusiasm arising usually from his actual association with power-systems engineering, either in industry or in utility engineering practice.

The teacher must therefore be undergirded. If appropriate research projects can be found, they become one of the most powerful forms of incentive to the engineering student. There are also other ways, such as engineers moving into teaching from industry and from utility engineering practice, engineer-and-teacher interchange on a yearly basis, vacation employment, lectureships, and teacher participation after industry retirement. Engineering tools are necessary, also, and these will have to continue to be supplied. A goodly participation in these ways should go far to correct the situation described by Dr. W. A. Lewis, that the engineering graduate of today is relatively less well prepared to take his place in the electric power field than he was twenty-five years ago.

Here is a need to be met. Whatever is done will be a contribution to more of the greatest of wonders yet to come; those for the use of mankind directly, and those for the great electric power systems which make this use possible.

Everett S. Lee

IMPORTANCE OF GRADUATE WORK IN THE POWER FIELD

Suggestions for achieving adequate personnel, adequately trained to meet present and future requirements of power-systems engineering through the co-ordinated efforts of industry and educators, together with research in promoting and encouraging graduate work by the power engineer

By Dr. W. A. LEWIS
Dean of the Graduate School
Illinois Institute of Technology, Chicago, Illinois

ONE of the vital problems of today is the education and training of young engineers who enter the electric power industry. Although the electric power industry includes many phases of industry and manufacturing, in this article particular attention will be directed to the training of engineers for the public utilities supplying electric power service and for the application groups of the manufacturing companies which supply the equipment needed by the public utilities.

CRITICAL NEED FOR POWER ENGINEERS

In large measure, the engineering staffs of the public utilities in the United States entered the industry in the decade from 1920 to 1930. Most of these men were college graduates and entered the industry after receiving the bachelor's degree following a four-year electrical engineering course in one of the colleges or universities in the United States. On the basis of a normal retirement age of 65 years, which will be prevalent at the time this group retires, these engineers will retire in the period from 1963 to 1973; that is, in the next 12 to 22 years. During the depression years and the years of World War II, the additions of young engineers to the power industry were relatively few in number. With the continuing growth of the power industry, it is evident that almost complete staff replacements, and additions to keep pace with growth, must be made so that trained staffs will be prepared to take over the major engineering duties in a few years.

The 1925 Graduate Engineer

In considering the present engineering group, the education of the electrical engineering graduate of 1925 could be regarded as typical. At that time, an educational program of four college years leading to a bachelor's degree was standard, and advanced work leading to a master's or doctor's degree was extremely unusual. The four-year graduate found himself reasonably well trained for the problems of the power system which he encountered at that period. Although the curriculum at that time was not considered to be specialized, it contained little or no training in electronics and communication or radio—an essential p of every electrical engineering curriculum today. F thermore, the emphasis on the broadening of the o look of engineering graduates has resulted in increas emphasis on liberal studies and humanities in the c riculum, with resultant decrease in technical conte Thus, in comparison with the four-year engineeri curriculum of today, the curriculum of the graduate 1925 would be considered as a specialized curricul in the power field.

Upon entering the power industry in 1925, the el trical engineer was frequently subjected to a traini program of one year or more, conducted by the utili or by the larger manufacturing companies, from wh the engineers were later recruited by the utility co panies. These training courses varied greatly but cluded studies of the planning, design, and operati of the power systems of that day, and of the appara and its characteristics available at that time. Furt training was, for the most part, accomplished by perience on the job, by attendance at technical soci meetings, and by self-study.

Technical Requirements

In the twenty-five years which have intervened, technical requirements of electric power systems ha grown enormously. In 1925, reliable and accur short-circuit analyses of power-system unbalanced fau were almost unknown. The methods of symmetri components and similar related components by wh these problems are regularly solved today were th considered the tools only of the advanced theorist. T entire technique of lightning protection, involving analyses of impulses and traveling waves, insulat co-ordination, and apparatus protection, was unknov Load and frequency control to a high degree of accur were dreams rather than realities. Moreover, the conc of reactive power and the control of reactive power voltage regulation were unknown. Instability of power system was considered more an act of God th as an error in planning or operation. Then, too, p tective relaying was confined largely to overcurr relaying, and high-speed protective relaying was known except in special applications.

This article was presented as a Conference Paper at the Winter Meeting of the AIEE in New York City on January 26, 1951.

eering Developments

is apparent to anyone familiar with power systems e present day who has read the brief recital of eering as viewed in 1925 that tremendous engi- ng developments have taken place. Although the nt engineering staffs have met these developments ively and have applied them generally to power ms throughout the country, the necessary knowl- of new developments has been gained the hard and is not nearly as widespread or as thorough as uld be for the most effective utilization of engi- ng developments.

ny engineers who could profit by knowledge of developments have not had the opportunity for ing in the advances that have taken place; they rely on others, meager knowledge and half truths, ften on copying of practices of other utilities which or may not be most effective for their particular lems. It seems almost self-evident that substantial ovements in power-system planning, design, con- tion, and operation could be effected if the public y and manufacturing engineers were fully familiar the important developments of the intervening s.

ADEQUATE TRAINING PROGRAMS

e knowledge and techniques applicable to power- m problems which have been developed over the twenty-five years and which are continuing to lop at a rapid rate have frequently been given the "power-systems engineering," a term which is ng into more frequent use daily in the industry, in ational circles, and in engineer-recruiting programs. e young engineer being recruited today is to be able lve the power-systems engineering problems of the ediate future, it is essential either that he come pped with education in this special field, or that uate training programs be set up to provide him the specialized training and knowledge needed his entry into the industry.

amental Preparation

e problem which confronts educators and those in stry responsible for personnel recruiting is to de- ine what part of the education should be completed llege, and what part of the training should be loped on the job. It is usually agreed by both ps that the colleges should teach the fundamentals, the applications should be left to industry. How- such a decision does not solve the problem because then necessary to decide what is fundamental and is applied education. The definition of a funda- tal subject will differ widely from engineer to eer, but many an engineer will define as funda- al all of the specialized knowledge needed to solve echnical problems of his present position. Because equirements of technical positions differ so widely, obvious that the composite fundamentals of all eers in the public-utility business would be beyond cope of any college curriculum, no matter how long.

Nevertheless, there is a growing conviction that the fundamental preparation for power-systems engineering must include sound knowledge of some or all of the following subjects:

(1). The behavior of long transmission lines where the effect of distributed capacitance is important
(2). The basic behavior of impulses and traveling waves
(3). Electric transients in circuits and machines
(4). Symmetrical and related components for the analysis of unbalanced polyphase systems
(5). Power limits and the elements of power-system stability
(6). Basic lightning phenomena
(7). Electric fields and high-voltage phenomena, including corona and radio influence
(8). Principles of protective relaying.

Some public utility engineers would add subjects to this list; others would delete some of the subjects listed as being in the field of the specialist rather than required knowledge for the typical engineer.

Today's College Curriculum

Regardless of whether full agreement can be obtained on the preceding list of fundamental topics, almost none of them were included in the typical college education of the engineer who graduated twenty-five years ago. In the curriculum of today some treatment of the first three topics of the list is usually included. However, the coverage is limited and often arranged to stress the effects prominent at the higher frequencies of communication circuits. If the remaining topics are treated at all, they must usually be elected as part of a limited option in power which the larger colleges and universities may offer; but not more than one or two of these topics can be covered, even briefly, without the omission of broader and more fundamental topics usually considered essential in any engineering curriculum.

Furthermore, because of the time spent on basic electronics, communication, and radio, which were almost unknown in college curricula twenty-five years ago, and the increased emphasis on liberal studies, the time available for polyphase circuits and transformers and for rotating machines is almost surely less than it was twenty-five years ago. Thus, in some respects, the graduate of today has a less thorough knowledge of topics of basic importance to power systems than his fellow graduate of twenty-five years ago. On the other hand, he is far better prepared than the earlier graduate in his knowledge of electronics, communication, and radio, all of which are making important invasions into power-systems engineering with applications to control, relaying, dispatching, communication, and metering. It should also be true that in general he has a somewhat better knowledge of economics, perhaps accounting and finance, public speaking and the humanities, than his predecessor.

It is shown by this comparison, that the student engineer, as he graduates from a four-year college curriculum, is relatively less prepared to meet the present needs of an engineering career in the power-system field than were the present engineers at the time of their graduation.

Supplemental Education

It is as true today as it ever was that the training of an engineer is never complete, and that he must continue to develop as long as he practices the engineering profession, if his work is to be crowned with a full measure of success. This means that the young engineer, as he leaves college, must not think that his education is complete, but that he must plan to apply himself to the study of technical problems in the future as they are encountered. New problems arise, and new solutions must be found. Thus, the education of the engineer is only partly obtained in college and must be supplemented on the job throughout his career.

PROGRAM FOR THE FUTURE

Thus far this analysis has been concerned largely with power-systems engineering as it is today. With the current developments which are taking place at a rapid rate, it is foolish to think that equally important developments will not continue to take place during the next twenty-five years if the electric power industry is to keep pace with its needs. The engineers entering the industry today must be prepared not only to meet the present problems but also to solve the problems of the future by knowledge gained from everyday operations in the industry. Therefore, it becomes increasingly evident that additional training must be supplied to those young graduate engineers who are to fulfill the important places in the power-system field during the next 10 to 25 years.

Graduate Work vs. Industrial Training Programs

With the new problems which must be met, it is almost unthinkable that preparation to meet the current problems must be acquired in the same painstaking and slow way it has been acquired by the present engineers. The alternative and, for many of the subjects listed, the far more efficient way is to provide training in organized courses, given either as graduate work in the colleges, or as part of graduate training programs in industry. Which of these two alternatives is adopted is not of vital importance. The important thing is that either one or both of these alternatives be adopted and developed to the fullest. Yet, at the present time, few colleges and universities offer a graduate training program in the power-systems engineering field encompassing satisfactorily all or most of the more fundamental topics listed previously. On the other hand, rapid growth has taken place in graduate work in electronics, communication, radio, and radar.

Few utility systems have augmented their programs to include effective coverage of the necessary subjects. In general, only the larger utilities are equipped or can afford to develop and offer training programs which are adequate for their needs. Thus, it would
seem that if the job is to be done, it must be
by the colleges, in the form of graduate courses, lea
perhaps to the master's degree. In metropolitan cen
evening graduate courses for employed engineers
be used effectively, but this will not serve for the
neers employed in the smaller cities. Thus a grad
college year seems necessary for the job in
instances.

The industry is not yet accustomed to seeking
but the four-year graduate. Yet, if the colleges are t
the job outlined here in a satisfactory manner,
essential that the public utilities and manufacturer
their own interest, give recognition to the value of
training required, by recruiting engineers who have
training, and by offering salary inducements which
repay the student for the time and effort spen
obtaining a year or more of specialized training in
power-systems engineering field.

Sponsored Research in the Power Field

Also there is almost complete absence of spons
university and college research in the problems of
electric power industry. The opinion is widely
today that the colleges and universities of the Un
States must carry on far more fundamental rese
than ever before, to continue and expand the deve
ments and basic knowledge which, prior to World
II, came largely from Europe. With the devastatio
Europe, resulting from the war, progress of fu
mental research in Europe has become almost
existent. Although the United States has excelle
applied research and development, most of the b
ideas of the past have been imported from Europe,
development to commercial fruition has been made
industry in the United States. To provide adeq
preparation for the future, expanded and augme
research of a fundamental character must be develo
in the United States, in an atmosphere free from c
mercial urgency and sales pressure.

In many fields since World War II, extensive
grams of fundamental research have been develo
with industry or, for the most part, government s
sorship. Tremendous programs in electronics, se
mechanisms, radio and television, guided missiles,
other phases of electrical engineering have been
veloped, and the colleges have participated widel
these programs. On the other hand, little or no spon
ship has been provided by industry, the government
any other source, for the support of fundame
research seeking the solutions of problems confron
the power-system industry. Although it may be
that the problems of the industry are less acute
critical than problems in other phases of the elect
industry, there are many problems which are
unsolved. It is also true that many of the problems
solved satisfactorily in the power field involve
critical research by the chemist, metallurgist, or
physicist, than research by the orthodox elect
power-system engineer.

netheless, the almost complete absence of current sored research programs of interest to the power stry turns the young electrical engineer with an sitive mind and, perhaps more importantly, his ssors to the more glamorous and immediate lems of other fields. The result is that the student e turn of mind would inspire him to seek advanced ing, in order that he might be prepared to solve rch and development problems more adequately s future career, turns away from power-systems eering. Yet, in the long run, there are few in the r industry today who would admit that the stry does not require the services of the most etent engineers to be found so that the continued opment of the electrical industry can keep pace developments in other fields.

ing Pace with Developments

other phases of the electric power field not pre- d in detail the situation is similar. In nearly every e important technical developments have taken with which the engineer should have a thorough ledge, rather than a vocabulary acquaintance, he enters upon his career. Yet the increasing sification in education required by the develop- of the industry makes possible less penetration r than more.

hough improvement in methods of presentation the elimination of less essential material have d to keep pace, these factors alone are inadequate. example, the development of automatic process ols and automatic devices in nearly all phases of stry require that the competent industrial engineer oroughly familiar with transient phenomena, feed- control systems, servomechanisms, and magnetic ifiers, as well as industrial electronics, all of which important fundamental aspects that are best t in organized classes because they are not easily bed on the job. Yet none of these topics was in- d in the engineering curriculum of twenty-five ago, and there is little room for them in the four- curriculum of today.

nilarly, a designer of large electrical equipment ly requires a thorough training in the recent developments of heat transfer, and would profit greatly, for example, by further study of electric and magnetic fields and fundamental behavior of solid, liquid, and gaseous dielectrics. Yet any comprehensive treatment of these topics is beyond the range of the four-year curriculum, and is not easily acquired. And so it is with other aspects of the power field.

Conclusions

There have been in the past, and will be in the future, many electrical engineering graduates employed in industry who do not require a high degree of specialized training. However, the day has arrived when the truly competent professional electrical power engineer has need for a group of fundamental subjects requiring more than the usual four-year curriculum to provide them. Formal graduate training in adequately organized courses is essential to meet these needs. It is the task of the colleges and industry to work together in meeting these needs for this purpose. The conclusions which may be drawn from the preceding presentation are:

(1). The electrical engineering graduate of today is relatively less well prepared to take his place in the electric power industry than his predecessor was twenty-five years ago

(2). Further graduate training, either in the colleges or in formal courses organized as part of industry training programs is essential if the graduate engineer is to be prepared to meet the present and future problems of the industry on a truly professional engineering level

(3). Few industry organizations are able to provide adequate graduate training programs in their own organizations

(4). If colleges and universities are to provide the necessary training, greater encouragement is needed in the form of more adequate inducement to students selecting graduate training programs, and in the form of sponsored research within the colleges.

Acknowledgment

Acknowledgment is gratefully made to E. R. Whitehead and E. T. B. Gross for assistance in the preparation of this paper.

IGHTS AND SIDE LIGHTS

Receivers for Civil Defense

pecial FM radio receiver has been oped for use by Civil Defense organi- s having two-way radio systems at command. The new receiver was an- ced at a recent meeting of electronics lists at Electronics Park, Syracuse .), at which latest developments in eld of emergency radio communica- were reviewed.

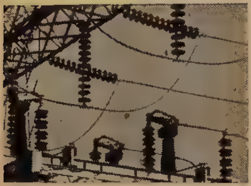
der a broad program of assistance e electronics field to civil defense izations, these experts are prepared r technical assistance to communities civil defense organizations in the planning of efficient emergency communications systems. It was explained how effective communications can help reduce hardship and loss of life when disaster strikes in peacetime as well as wartime.

A novel feature of the unit allows civil defense headquarters to broadcast messages to all groups at once or to separate groups individually. Thus a group hears only messages it is intended to receive. Each receiver is inactive until turned on by headquarters. In addition to receiving messages from civil defense headquarters, it can, if desired, be used to automatically start and stop air-raid sirens or other warning devices. The push of a button at headquarters broadcasts a special tone which, when received by the new instrument, operates a switch to activate the warning-device system.

Two models of the new receiver will be produced: one will operate in the 30–50 megacycle band of the radio-frequency spectrum, and one in the 152–174 megacycle band. Both are designed to operate on standard 117-v a-c supply; however, an inverter will be available to permit operation from a six-volt storage battery. The receivers are double-conversion superheterodyne types, with two separate crystal-controlled oscillators.

PROGRESS AND TRENDS IN HIGH-VOLTAGE TRANSMISSION

Proper interrelation of many factors is the basic problem of economic power transmission. Experience, supplementing analytical study, gives opportunity for realistic surmise in regard to future practice



By S. B. CRARY
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General Electric Company

HIGH-VOLTAGE transmission is undergoing rapid development. In view of recent advances(1)(2) it may be worth while to appraise this progress and to indicate the expected trend for the future. FIG. 1 shows a plot of the highest a-c transmission voltage versus years, beginning with 1885, the year in which a-c transmission was made possible by Stanley's invention of the transformer. It is interesting to note that the time between steps to a higher voltage appears to be increasing.

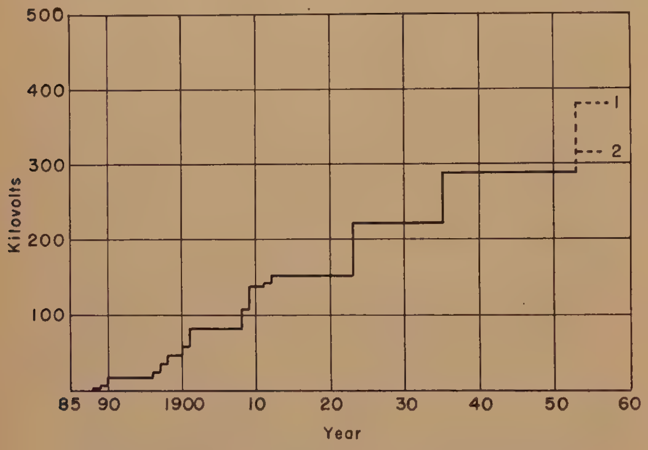


Fig. 1. Highest Transmission Line Voltage versus Year
Dashed lines indicate approximate expected operation of new high-voltage systems.
Curve 1 applies to Reference (1)
Curve 2 applies to Reference (2)

Economic Capability of Transmission

Much theoretical work has been directed toward determining the economic capability of transmission. Losses are the primary limitation determining the economic capability of a transmission circuit. The reactive losses can be compensated for by synchronous condensers and capacitors, the real losses reduced by larger or lower-resistance conductors.

Stability previously was an important obstacle for the reliable transmission of power over long distances. However, stability compensating means are now available so that the stability limitation can be removed for less than 15 percent of the cost for transmission (includes step-up and step-down transformers) for a straightaway line 600 miles in length. Stability compensating means become necessary economically straightaway distances above about 250 miles. series capacitor provides a benchmark for determi the relative cost of such stability compensating m ods.(3)(4)(6) Below 250 miles, the necessity for sp stability compensating means does not at present pear to exist, at least for conductors up to a co equivalent of about 800,000 cir mils.

FIG. 2 shows a curve indicating the approxi economic capability for transmission (per circui terms of the surge-impedance loading). Table I the surge impedance loadings in kilowatts for re sentative voltage levels. This capability curve, F is somewhat approximate in that it is based up number of economic studies(4)(5) but shows ra concisely one of the important aspects of high-vol transmission. Also shown in FIG. 2 are points indica the major transmission line loadings in the U States before World War II.(7) As will be noted, siderable spread exists in these loadings which re prewar concepts of power transmission. The req ments during World War II made necessary n greater loadings on circuits than those for which

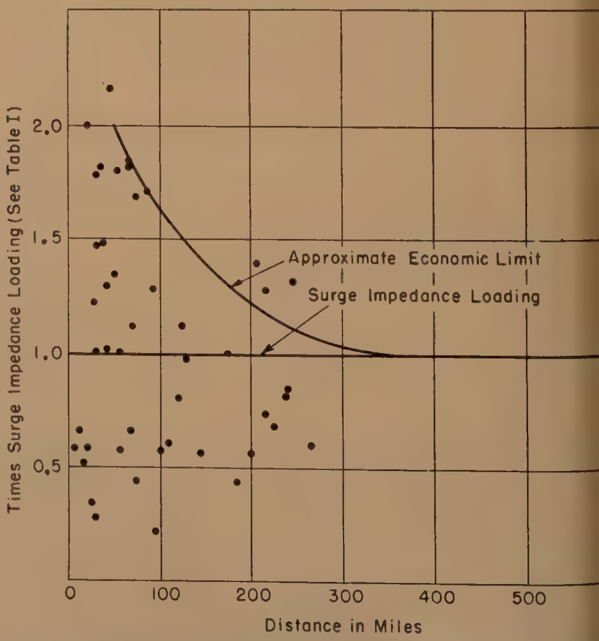


Fig. 2. Approximate Transmission Economic Capability in Term Surge Impedance Loading (Table I). Also shown by dots are the M Transmission Line Loadings in the United States before World War I

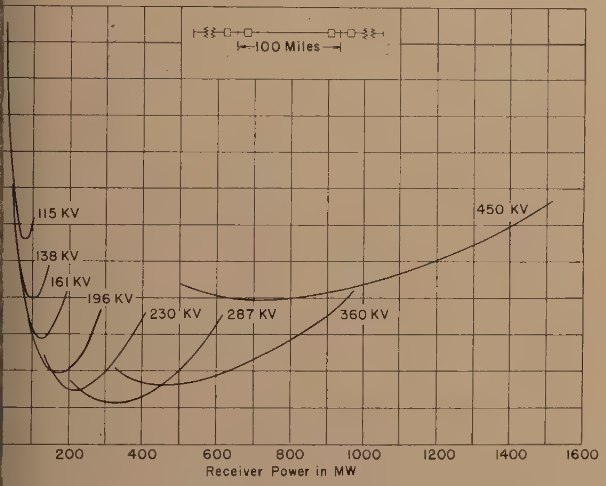
This article was presented as a paper at the Midwest Power Conference in Chicago, April 4, 1951.—EDITOR.

(1) Numbered references are listed at the end of the article.

designed and gave confidence that reliable opera- could be obtained more nearly approaching the omic limit shown, provided the conductors were lly designed so as to avoid excessive losses at the r loadings.

omic Studies

veral economic studies have been made during the ew years which are quite consistent in their over- nclusions.(4)(5)(8) Typical of the economic results(4) hose shown in FIG. 3 for a 100-mile line having an atio of 0.1 corresponding approximately to a con- or of 800,000 circular mils copper equivalent. It e noted in FIG. 3 that, for this particular economic using 1945 costs, the most economic voltage (of oltages chosen as parameters) is 287 kv transmit- about 330,000 kw per circuit. It will be noted also there is very little difference in the cost of trans- on between 230, 287, and 360 kv in the region of most economic loadings, all within one twentieth mill per kw-hr of each other; and that the higher oltage the greater the range in loading which may otained with good economy of transmission.



3. Mills per Kilowatt Hour versus Receiver Power in Megawatts ical of Economic Studies (4))

No line compensation
Load factor =50 percent
Annual charge =11.5 percent
x =0.8 ohm per mile
b =5.2 ×10^{-6} mho per mile
Conductor resistance =0.08 ohm per mile

e increase in cost of transmission with a voltage as 450 kv is due chiefly to the increasing cost of ransformers per kva as the voltage increases. Also ll be noted that, as the voltage goes up, the most omic power transfer per circuit goes up quite lly, such that for 360 kv this becomes 500,000 kw ircuit for 100 miles. If dual conductors were used, optimum loading for 360 kv at 100 miles would ase to approximately 625,000 kw per circuit.

other typical result(4) is shown in FIG. 4, which the cost of transmission, including the step-up step-down transformers and intermediate switch- tations with no line compensation. This shows that nost economic voltage (for the conditions of this particular study) as the distance increases varies from 300 kv for a 200-mile line to 400 kv for a 600-mile line. However, as indicated, there is very little difference in the cost as a function of voltage in this range of 300 to 400 kv, so that local conditions may more than likely determine the optimum voltage.

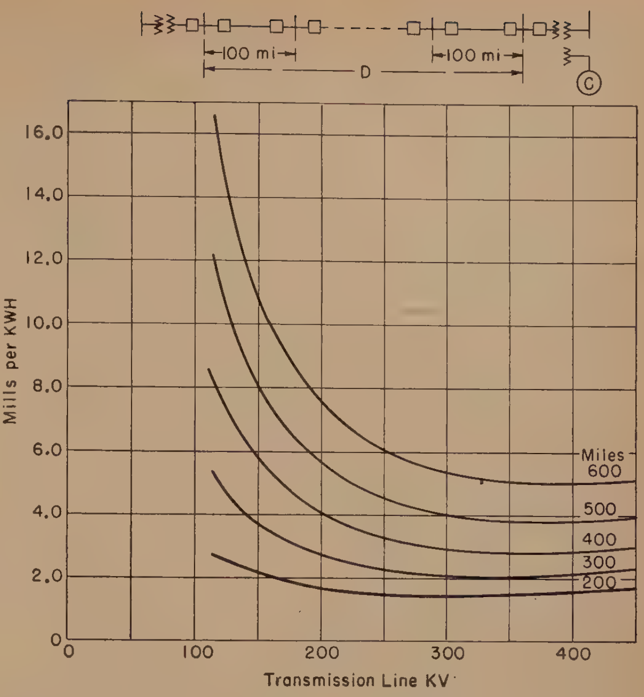


Fig. 4. Mills per Kilowatt Hour versus Transmission Line Kilovolts

(Typical of Economic Studies(4))
No line compensation
Intermediate stations every 100 miles
Load factor =50 percent
Annual charge =11.5 percent
x =0.8 ohm per mile
b =5.2 ×10^{-6} mho per mile
Conductor resistance =0.08 ohm per mile

A very important factor is introduced(5) in the variation in cost between the use of a double- and a single-circuit tower line. Double-circuit tower lines at these voltage levels, which in general require steel towers for both the single- and the double-circuit towers, make it desirable from an economic standpoint to select a voltage which allows for the use of a double-circuit tower. For a given amount of power in

TABLE I

SURGE IMPEDANCE LOADINGS (S.I.L.) PER CIRCUIT FOR REPRESENTATIVE VOLTAGE LEVELS

Line kv	Single Conductor S.I.L.* (kw)	Dual Conductors S.I.L.** (kw)
115	33,000	—
138	47,600	—
161	65,000	—
196	96,000	—
230	132,000	165,000
287	206,000	257,000
315	248,000	310,000
360	324,000	405,000
450	505,000	631,000

*Surge impedance kilowatt loading per circuit when the surge impedance is 400 ohms, corresponding approximately to high-voltage circuits using single conductors per phase

**Surge impedance kilowatt loading per circuit when the surge impedance is 320 ohms, corresponding approximately to high-voltage circuits using dual conductors per phase a tower head, it appears at these voltage levels for conditions usually prevailing in this country, particularly when right-of-way costs are appreciable, that the double-circuit-tower line is more economical than the single-circuit tower line. In other words, a voltage level such as 300 kv which is capable of using double-circuit towers can be expected, for many of the conditions prevailing in this country, to be more economical than a voltage of 380 kv which requires a single-circuit dual-conductor line wherein each tower head, the double-circuit 300-kv tower, and the single-circuit dual-conductor 380-kv tower, will have a total surge-impedance loading of about 450,000 kw. It was found(5) that it was most economical to use as high a voltage (in the region of 315 kv) as appeared possible at the time, which could be used with a double-circuit tower.

It has been found also(4)(5) desirable to use intermediate switching stations at about 100-mile intervals for the longer-distance double-circuit lines. With increase in the number of paralleled circuits, the economic distance between switching stations increases.(5)

As an aid in visualizing better the component costs of transmission, Tables II and III show a breakdown of costs for a 50-mile transmission single-conductor per phase at 315 kv and a 600-mile transmission dual-conductor per phase at 380 kv. It will be noted that, for the shorter distance of transmission, the kw losses are the more important item; whereas, for the longer line, the investment cost of the line is the largest item.

Economic studies(7)(9) indicate almost a linear relationship of the cost of transmission in mills per kw-hr versus miles as shown in Fig. 5, which also gives a comparison between electrical transmission and other methods of transmitting energy. The load factor is very important in such a comparison, because high load factor may very well result in straightaway electrical transmission becoming more economical than transportation of coal by rail car even for distances exceeding 200 miles.

Conductors

The method used in evaluating the losses for transmission will depend upon the prevailing local conditions. One of the more acceptable methods is to use a capacity charge plus an energy charge.(4)(16) If it is assumed, for example, that the capacity charge for the losses is $150 per kw and the energy charge is at 4 mills per kw-hr with a load factor of 50 percent, an evaluation of losses is obtained as shown in Tables II and III for the 50- and the 600-mile lines. These results point very definitely to the desirability of using low-resistance conductors for transmitting large blocks of power. It is interesting to note the use of about an 800,000-cir mil copper equivalent conductor in the 300/315-kv system(2) in this country, whereas the Swedish dual-conductor line(1) is built with each conductor having 650,000-cir mil equivalent copper conductor or 1,300,000-cir mils equivalent copper conductor per phase.

One of the difficult problems in appraising the economic conductor is to obtain an accurate indication of the change in the cost of transmission circuits per mile w decrease in resistance of the conductor. The econom of bulk transmission, however, indicate that cond tors above 800,000-cir mils copper equivalent are doubtedly fully justified except when other local cumstances may prevail. In one instance,(2) for ample, the use of lower resistance conductors is te pered by the requirement of being able to melt sl

Based on such economic evaluations of the I^2R l the corona and radio-interference problems become critical in determining the conductor diameter exc for voltages above 287 kv. When voltages above kv are used, corona and radio interference proble become more important factors in determining(1)(10) to the conductor diameter; and special expanded dual conductors may be required. It has been indicate that dual conductors have resulted in an over saving as compared with single conductors. The use dual conductors can be expected to be further evalua for the different conditions prevailing in this coun along with the economics of lower-resistance single c ductors per phase.

TABLE II

COMPARATIVE TRANSMISSION COSTS

315 kv—500 mw
50 Miles—Single Conductor—$r/x = 0.1$

		$—Millions
Transformers		5.00
Transmission Line		1.75
Circuit Breakers		1.00
Kvar Losses		1.40
Kw Losses: Line		3.36
Transf.		1.81
TOTAL		14.32
Corresponds to:	$28.7 per kw 0.75 mills per kw-hr (50 percent load facto	

Line Insulation

The level of line insulation for a given voltage pears to be taking a downward trend, in that fewer sulator disks are being required for a given volt

TABLE III

COMPARATIVE TRANSMISSION COSTS

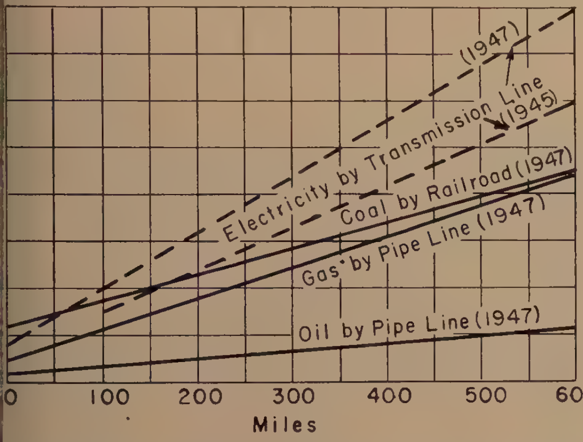
380 kv—450 mw
600 Miles—Dual Conductor—$r/x = 0.075$

		$—Millions
Transformers		5.85
Transmission Line		33.00
Circuit Breakers		5.60
Kvar Losses		0.45
Kw Losses: Line		10.38
Transf.		1.63
Compensation		5.10
TOTAL		62.01
Corresponds to:	$138 per kw 3.6 mills per kw-hr (50 percent load fact	

This possibility has been fully recognized and ssed elsewhere.(14)(15) A wide spread has been l(14) in the number of insulator disks used at a voltage level and engineering factors have been ed(15) in determining the number of disks. This may be expected to continue with increased ience. Some of the important factors in allowing his have been the increased use of high-speed re- ng(2) which has decreased the relative importance e faults due to lightning, as well as the reduction ontrol of switching surge overvoltages by the use odern circuit breakers,(17) particularly those of the lse type.

inal Equipment Insulation

duction in transformer insulation by one step for ively grounded-neutral systems is rapidly be- ng standard practice in this country at voltages of v and above, resulting in important savings in the of transmission.(2)(18) Some reduction in the in- ion level of circuit breakers has already taken and can be expected to become better formulated e near future. The circuit breaker, however, as a ctive device may require more margin in its volt- nsulation, particularly as it may be required to nnect portions of a system after some of the nded sources have been removed or it may be re- d to interrupt during out-of-step conditions, re- ng in high voltages across the switch. Inasmuch as requirements for a protective device may be determining of the insulation limits than the im- -voltage levels to ground, it may be expected that tions of circuit-breaker insulation will be quite ed.



5. Comparison of Electrical Transmission (50 percent load factor) Other Methods of Transmitting Energy. Reference (4) gives 1945 s; Reference (9) gives 1947 Costs.

rupting Capacity

ly four years ago interrupting capacities were pre- d as increasing from 5 million kva to as high as 10 on kva for voltage levels 230 kv and above.(19) prediction has more than come true in that inter- ng capacities of 12 million kva have been obtained 0 kv, and 15 million kva is being considered(2) at 315 kv. This trend makes possible the use of more closely interconnected high-voltage systems and is in the direction to decrease the cost of transmission by allowing for the transfer of larger blocks of power per circuit.

Kvar Control

Generator and synchronous-condenser voltage regulators have undergone important improvements in the last few years, such that increases in the reliable power limits of systems are now realizable by the use of modern voltage regulators which have no dead band. This is also of value in providing under-excited capacity for the line-charging requirements of these high-voltage circuits, reducing the necessity of using such means as switched shunt reactors. Increased applications are also being made of shunt-switched capacitors directly connected to increasingly higher circuit voltages.

D-c Transmission

D-c transmission appears to be relegated to underground and under-water cable transmission of electrical energy. A-c transmission, because of its great flexibility and the very material progress which has been made in recent years in reducing the insulation level of lines and apparatus by the improvement of lightning arresters and circuit breakers, has probably resulted in a complete economic victory of a-c transmission over d-c transmission for overhead lines. An important factor in this has been the increased use of relatively low-cost kvar sources to overcome the reactance losses of a-c systems.

Additional experience in the field of d-c transmission may be expected to be obtained in the near future. Some aspects of the future installation of a d-c cable circuit from the mainland of Sweden to the Island of Gotland have already been described.(20)(21)

Summary

(1). Progress in the field of a-c transmission has been quite rapid in recent years and is continuing at a good rate.
(2). D-c transmission appears to be no longer competitive with a-c on overhead lines.
(3). It is expected there will be a continuing trend to
  (a). Increased kilowatt loadings per circuit
  (b). Reduced line insulation
  (c). Reduced losses by the use of larger conductors, more efficient transformers, and kvar control.
(4). Additional developments in the field of high-voltage transmission can be expected in the direction of
  (a). Larger transformer and generating units
  (b). Higher interrupting capacity circuit breakers
  (c). Improved relaying
  (d). Increased interconnection of system
  (e). Development of operating procedures to reduce severity of transmission and generator outages.

(5). Voltages higher than the 300 to 400-kv range do not appear justified economically for the most extreme range of local conditions, even with a voltage in the lower part of this range appearing as best suited for conditions prevailing in this country.

Conclusion

High-voltage transmission is showing continued healthy growth. Although there appears to be no further economic advantage in increasing the voltage levels above the 300 to 400-kv range, the use of these higher voltages has opened up new opportunities to obtain more efficient systems.(22) The immediate future appears to be a period in which much effort will be given to improving the efficiency and capabilities of these new higher-voltage systems. The opportunities now apparent insure that as much progress will be realized during the next decade as was attained during the last, possibly more.

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HIGH LIGHTS AND SIDE LIGHTS

Glass to Metal—Soldered!

Glass can now be soldered to metal, in a process which makes a bond stronger than the glass itself. The method, which can also be used to solder metal to ceramics and carbon, is currently being tested for industrial application.

Glass and metal areas to be soldered are painted with a thin layer of titanium hydride, and solder is placed upon both painted areas. The parts are placed together and then heated under a vacuum. When the temperature reaches about 900 F, the titanium hydride decomposes, causing the solder, which has already become molten, to adhere to the titanium-painted areas of both the glass and the metal. A strong, tight bond is formed upon cooling.

By using soft metal solders, it is possible to subject this glass-to-metal seal to rapid temperature changes without danger of cracking, despite the wide difference in temperature expansions between glass and metal. This is possible because the di ences in movement are absorbed by solder.

Fulfillment of an engineering dream. The handle of this cup is a metal spoon, soldered to the glass in a process that permits the direct joining of glass to metal

The new technique is now in us aircraft ignition systems, and labora investigations have suggested possible plications in the manufacture of tr formers, capacitors, and electric mo These possibilities are now under sideration.

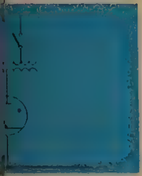
CORRECTION

In the article "Gas-turbine Pow Plant Completes Year and a Half Operation," by B. G. Hatch, in th March 1951 issue, an error appeare in the heading of Table I on page 1 The second line should read:

Equipment ratings: one 30,000-k steam turbine; one 20,000-kw stea turbine; one 3500-kw gas turbine

MPLISTAT REGULATORS FOR POWER RECTIFIERS

ew device used in industrial power rectifier control—notable its adaptability, wide range, low maintenance and simplicity



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General Electric Company

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HE adjustment of the direct-voltage, or direct-current, output of an ignitron power rectifier by e control of the ignitor firing time is a desirable re in many rectifier applications. Most power iers which have been manufactured in recent years been equipped with a phase-shifting arrangement n is capable of at least a 15 percent adjustment of lirect voltage. Many equipments have also been ufactured with greater ranges of direct-voltage ad- ent.(1)(2)

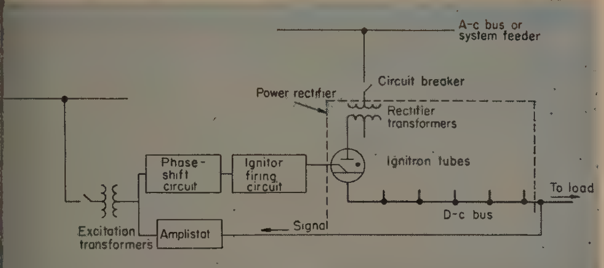

Fig. 1. Functional diagram of basic regulating system

ere are some classes of rectifier service in which regulation of the direct-voltage or direct-current ut of the power rectifier is just as important as the int of voltage adjustment available.(3)(4) In these cations a closed-loop regulating system is used, h incorporates some type of amplifier. The prin- function of the amplifier is to detect and utilize l changes in direct-voltage, or direct-current, out- n such a way that the original output value will be red. The performance of the regulating system is a sure of the accuracy and speed with which this is mplished.

ere are three basic types of amplifiers which can sed in the regulating system, namely, the electronic lifier, the amplidyne, and the amplistat. The elec- c amplifier uses vacuum and gas-filled tubes; the lidyne is a direct-current generator; and the ampli- is a magnetic amplifier. Each type has certain ianical and electrical characteristics which are d to particular types of service or particular regu- g requirements.(5) The amplistat is the only type ated in this article. It should be noted, however. the regulating-system characteristics which involve onstants of the rectifier power circuit will hold with type of amplifier in the regulating system.

Elements of the Regulating System

The principal elements of a regulating system for a power rectifier are the ignitor firing circuit, the phase-shift circuit, the amplistat, and the power rectifier itself, arranged as shown in Fig. 1. The characteristic of the phase-shift circuit determines the amount of direct-voltage adjustment. The combined characteristic of the amplistat, the phase-shift circuit, and the power rectifier determine the regulating performance, with a given a-c supply system and rectifier transformer. The characteristic of the ignitor firing circuit does not have any direct effect on the regulating performance.

Rectifier Regulating System

The performance of the regulating system depends upon the electrical constants of each of the elements in the system. The way in which the different constants affect the regulating performance is diagrammed in Fig. 2. The class of service of the particular rectifier installation determines its power circuit, which in turn determines the particular type of excitation system required. The application requirements determine whether the regulator is to hold constant direct voltage or current, and the amount of phase control of output voltage which will be required. The application requirements also determine the regulating performance and sensitivity which is required.

Unit substation for changing a-c to d-c

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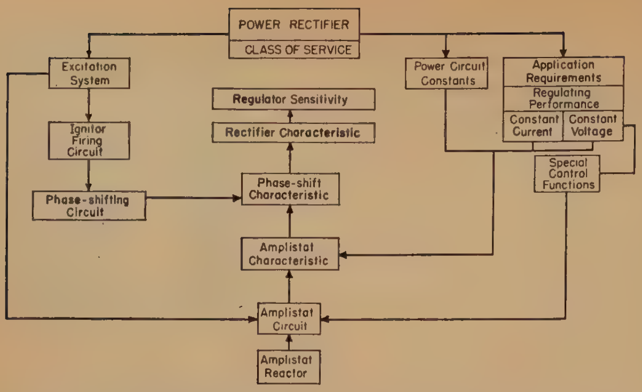


Fig. 2. Block diagram indicating constants and characteristics which affect regulating performance

Before the characteristics of the amplistat can be determined, it is necessary to consider three major factors: First, the control characteristic of the power rectifier itself; the second, the inherent regulation of the rectifier and the a-c supply system to which it is connected; and third, the regulator sensitivity required by the particular application or class of service. If a constant-current regulator is considered, the cemf of the load must be included.

The control characteristic of the power rectifier is a cosine function for the voltage regulator; and it is the product of the load characteristic and a cosine function for the constant-current regulator. The amplistat, phase-shift, and rectifier characteristics when combined in the regulating system produce the regulator sensitivity characteristic. The most simple way to represent these characteristics is by a series of curves, because the characteristic of each circuit is a nonlinear function. (The principal electrical component in each circuit is a nonlinear device.) It is possible to represent each circuit by mathematical relations, but the result is too complex and unwieldly for presentation here, or for general use.

It can be seen, therefore, that for best performance of the regulating system, there must be proper coordination of the rectifier power-system constants, and
the characteristics of the individual elements (circu
in the regulating system.

Additional application requirements which conc
special control functions are also indicated in FIG
Examples of these functions are: paralleling the recti
with other rectifiers or converters; changing from po
rectification to power inversion; or making the dire
voltage or current output responsive to some defin
signal. Such a signal might be derived from an indi
tion of position, speed, sequence, amplitude, phase,
time. Signals of this nature would introduce some mo
fication of the basic regulating action but would n
determine the sensitivity of the system. These add
functions, when present, would increase the number
control circuits required in the amplistat, as indica
in FIG. 2.

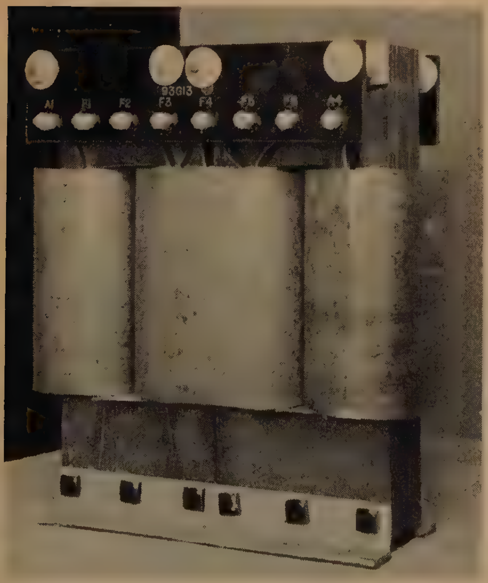
The Amplistat

The amplistat is an excellent device for use in pow
rectifiers because of the similarity between its com
nents and those of the other circuits in the excitat
system. It has several advantages, the most importa
being its ability to produce large changes in outp
current with very small changes in applied signal c
rent. It consists of transformers, reactors, resistors, a
selenium rectifiers, all of which are static compone
that are relatively free from the effects of moistu
dust, vibration, and mechanical wear. The major co
ponent is the amplistat reactor, which is made with
high-permeability alloy-steel core having multiple c
trol signal windings. The use of multiple control win
ings provides an effective means of combining, or m
ing, signals from different sources. Problems of isolat
circuits are simplified since each winding is fully
sulated from the others and from the core.

The control characteristic of the amplistat is det
mined by the electrical rating of the amplistat reac
and by the values of the amplistat circuit constants

Two typical amplistats for constant-voltage re
lators are shown in FIG. 3, one for 15 percent dir
voltage control and the other for 100 percent dir

Amplistat reactor unit used in regulators



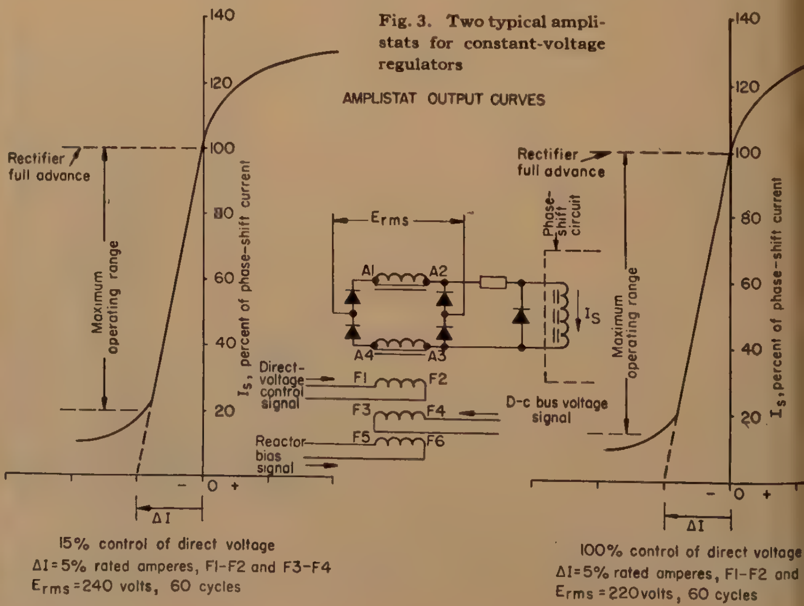


Fig. 3. Two typical amplistats for constant-voltage regulators

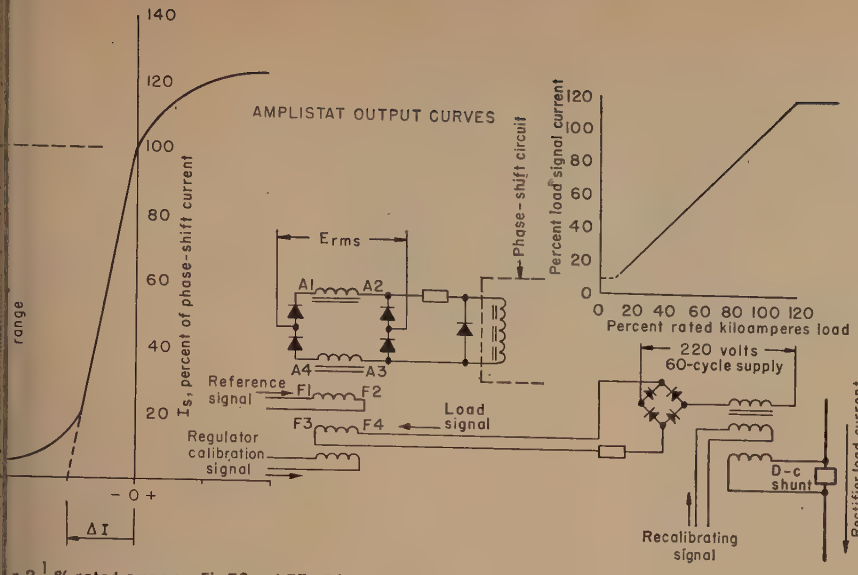


Fig. 4. Two magnetic amplifiers for constant-current regulators

= $2\frac{1}{2}$% rated amperes, F1-F2 and F3-F4

ms = 150 volts, 60 cycles

e control. The circuits and the control curves are r. The two amplistats differ only in kva rating. ant-current regulators use two magnetic amplias indicated in FIG. 4. They are connected in le. The first amplifier is not an amplistat since es not employ the self-saturating circuit. The l characteristic of both magnetic amplifiers is in FIG. 4. The use of two magnetic amplifiers s manner provides a proportional response to urrent changes and helps to keep reasonable of regulator components.

nt-voltage Regulators

operation of a power rectifier with a constantge regulator is illustrated by a graph in FIG. 5. s diagram the sloping line represents the directge output of the rectifier as the load is increased 0 to 100 percent rated load. The no-load voltage is ted by E_{do}, and the rated voltage by E_{dn}. To hold ant-load voltage, it can be seen that the angle of retard of the ignitor pulse must be continuously ted as the load is changed. The difference between oping line and the horizontal line E_{dn}, at any value d, represents the percent of voltage adjustment red.

quantity X shown in FIG. 5 is the total inherent ge regulation of the rectifier at *rated* load, and its represents the unregulated variation in direct ge from no load to full load. The regulator must e this variation to the specified value.

quantity D_o is the difference between the ceiling ge and the rated voltage at rated load, and its represents the percentage drop in system voltage hich the regulator compensates. In some special cations it may be necessary to provide regulation ne value of load above normal rating. For these ines, the quantities X' and D_o' are most conveniently ssed as a percentage of the no-load voltage E_{do}. manner in which the elements of the regulating n are combined are shown graphically in FIGS. 6

Fig. 5. Power rectifier operation with a constant-voltage regulator

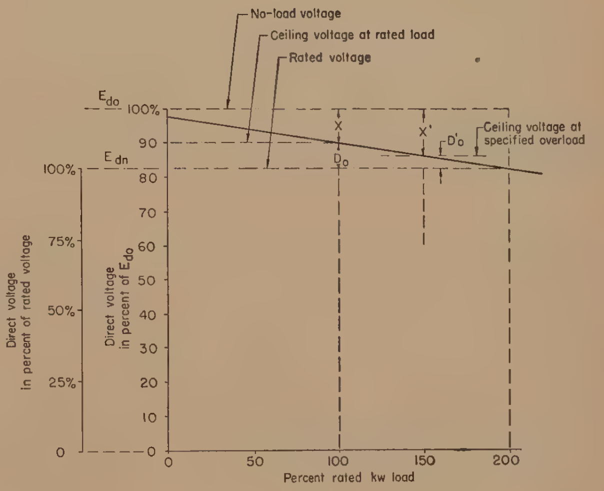
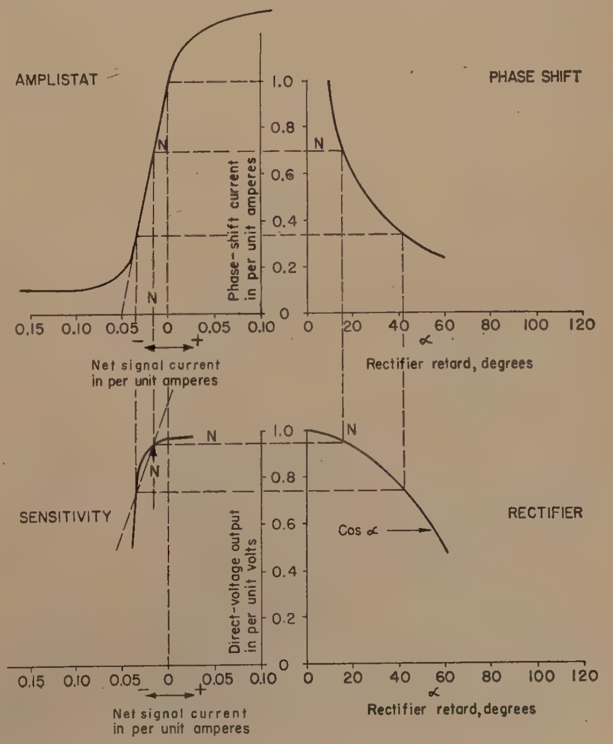
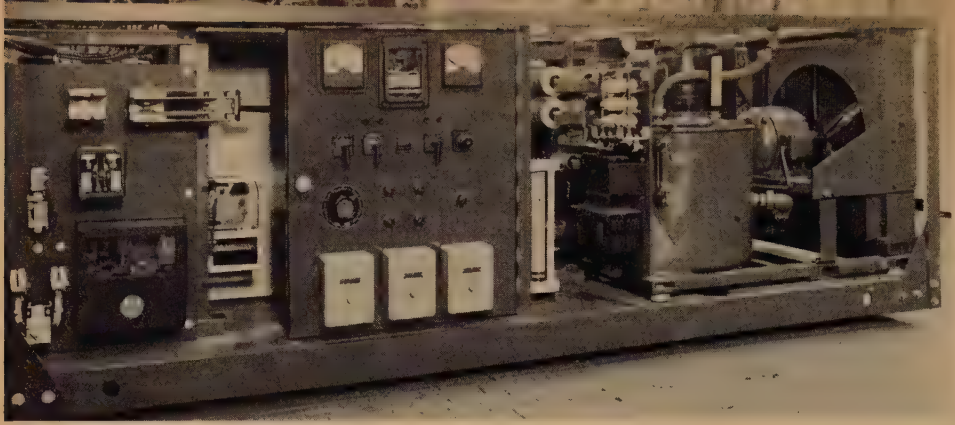


Fig. 6. Constant-voltage regulator, 15 percent direct-voltage control





and 7, for the 15 percent and 100 percent voltage control rectifiers respectively. The phase-shift characteristics shown are typical for each type of rectifier control. The rectifier characteristic shows that the direct voltage depends upon the cosine of the angle of ignitor shift from 100 percent to approximately 50 percent voltage. The amount of inductance in the rectifier load circuit determines the curve from 50 percent to 0 voltage.

The sensitivity curve is a plot of the variation in direct-voltage output against amplistat signal current, both expressed in per unit values. The sensitivity curve for any voltage regulator is obtained by multiplying together the control characteristics of the amplistat, the phase-shift circuit, and the power rectifier. The sensitivity curve for any regulator can be obtained experimentally by opening the regulating loop at the input to the amplistat. (That is, disconnect the amplistat d-c bus signal, shown in Fig. 1.) A small adjustable signal is then applied to the amplistat control winding, and the variation in direct voltage is noted as the signal is changed. The dotted lines labeled "*N*" in Figs. 6 and 7 indicate the normal position of the regulator at ra load, and with normal a-c supply system voltage plied.

The accuracy with which the direct voltage wil held depends upon, (1) the average slope of the s sitivity curve (in the operating range), (2) the am tude of signal from the d-c bus, and (3) the pow system constants X, D_o, E_{dn}, and E_{do}.

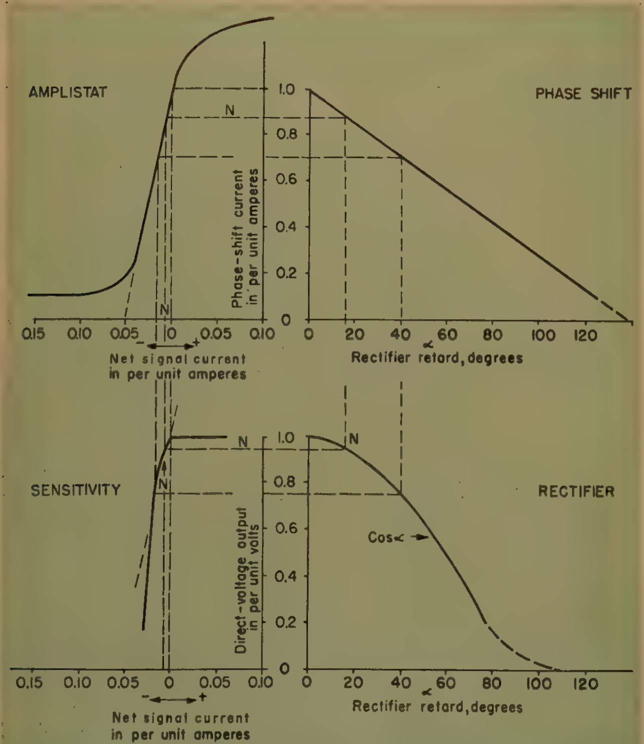


Fig. 7. Constant-voltage regulator with 100 percent direct-voltage control

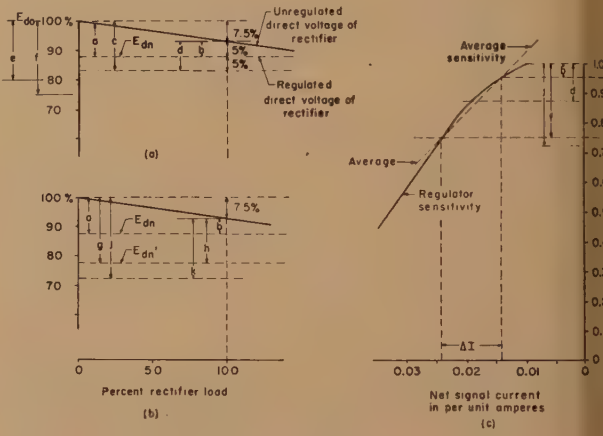


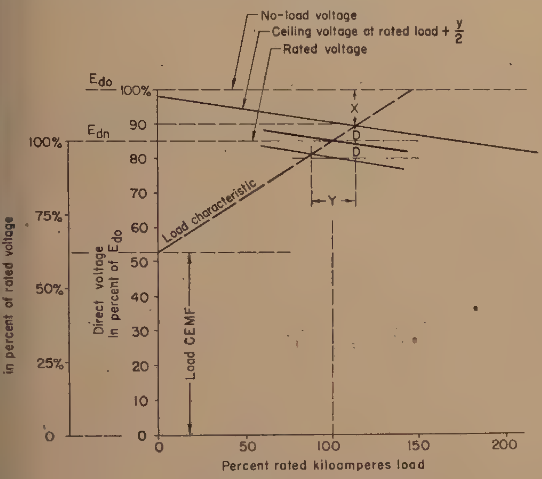
Fig. 8. Range of rectifier phase control

Recalibration of Voltage Regulators

It is sometimes desirable in many rectifier appl tions to provide some adjustment of the *regulated* v age. The amount of adjustment required is determi by the local conditions at a given installation and the ratings of the d-c equipment connected to the re fier. In general industrial service, this represent moderate range of adjustment, and only in some ticular applications is a full range of direct-vol adjustment required. This means a larger phase-co range will be required in those rectifiers which ha regulated output compared to those with purely ma control. This is illustrated by the diagrams in Fig In Fig. 8(a) the amount of phase control at no load at full load is indicated by the small letters *a* and normal system voltage. With a 5 percent drop in sys voltage, *b* goes to zero and the rectifier becomes f advanced. With a 5 percent increase in system volt *b* increases to *d*; and at no load, *a* increases to *c*.

If the regulator is recalibrated to hold a lower di voltage than E_{dn}, the increase in rectifier phase reta shown by Fig. 8(b). In Fig. 8(b), E_{dn}' is 90 percen E_{dn}, and the amount of phase control at no load ad is indicated by g and h respectively. With a cent increase in system voltage, the increased control is indicated by j and k. Standard phase-circuits for 15 percent voltage control provide ar shifts corresponding to the 25 percent reduction load voltage indicated by j in FIG. 8(b) and 8(c). adjustment of the direct voltage is accomplished lucing the amplitude of the voltage-control signal nt (FIG. 3) applied to the amplistat. When this is the d-c bus voltage signal will decrease and the stat will regulate a lower value of phase-shift nt.

sensitivity curve for a typical regulator is plotted enlarged scale in FIG. 8(c). The sensitivity of the n is usually measured as the average slope of this between 75 percent and 95 percent of the no-load ge. The sensitivity is expressed as the per unit e in direct volts divided by the corresponding per hange in amplistat signal current.



ig. 9. Power rectifier operation with a constant-current egulator

ant-current Regulation

e operation of a power rectifier with a constant-nt regulator is shown in FIG. 9. The rectifier ation curves and the system constants X, D, and

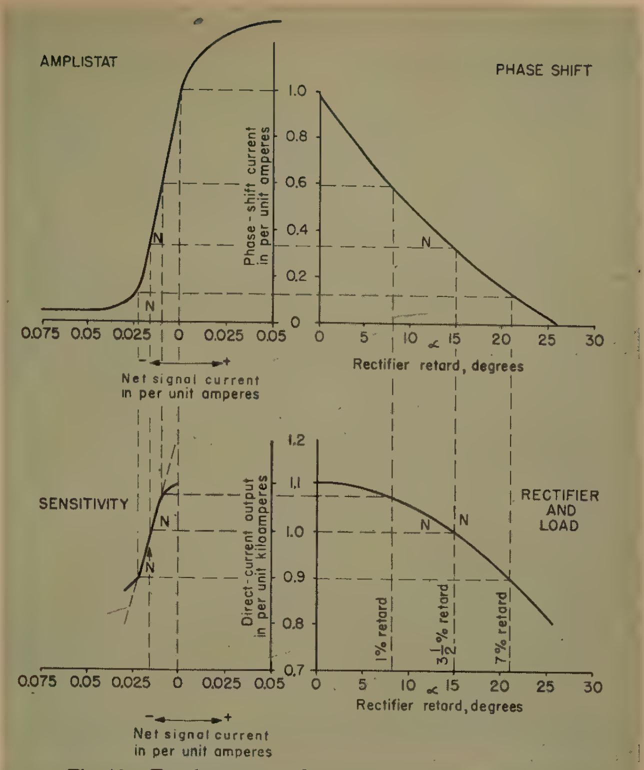
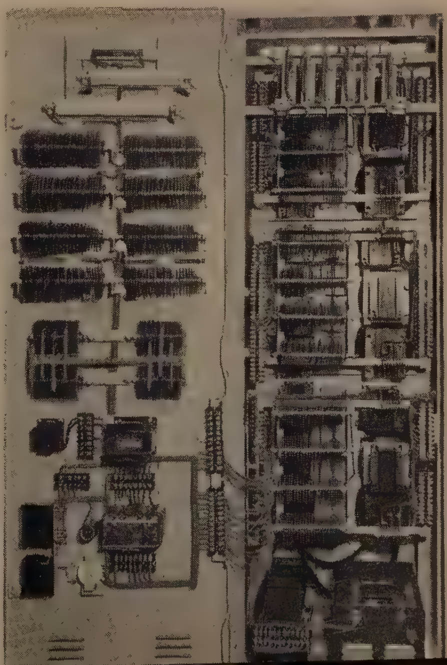


Fig. 10. Regulator curves for a constant-current regulator

E_{do} have the same significance as the corresponding constants in the voltage regulator. The quantity D represents the amount of system voltage change, or load voltage change, for which the regulator will correct. To determine the inherent current regulation, it is necessary to plot the volt-ampere characteristic of the d-c load. The resulting load current variation, which must be corrected by the regulator, is indicated by Y in FIG. 9.

The regulator curves in FIG. 10 show how the elements of the regulating system are combined. The characteristic of the first magnetic amplifier is not shown because its output is directly proportional to the power-rectifier load current. The rectifier characteristic is not a cosine function, but is a combination of a cosine curve and the volt-ampere characteristic of the load.

Type of rectifier used in general industrial application



Regulator mounted on rear door of rectifier cubicle

This is shown graphically in Fig. 11. The direct voltage varies directly with the cosine of the angle of phase retard. The load current at any value of direct voltage depends upon the volt-ampere characteristic of the load, as well as the value of direct voltage. The curves in Fig. 11 show how the curve of rectifier load amperes vs angle of phase retard is obtained. The curves in Fig. 11 also show that, when the rectifier is fully advanced, it will deliver slightly less than its rated ceiling voltage and approximately *110 percent* of rated load current. The dotted lines *N*, in Figs. 10 and 11, show the normal position of the regulator at rated load with normal supply system voltage. The calibrating signal indicated in Fig. 4 serves to adjust the regulator to operate over the linear portion of the amplistat characteristic.

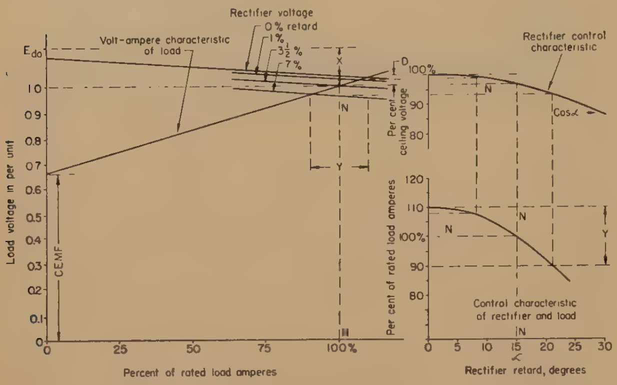


Fig. 11. Rectifier characteristics for constant-current regulation

The regulator sensitivity curve shows the variations in per unit direct-current load amperes against per unit signal current. This curve is obtained, as with the voltage regulator, by multiplying together all of the control characteristics in the regulating system. This curve can also be obtained experimentally by opening the regulating loop at the input to the amplistat in the same manner as with the voltage regulator.

The accuracy with which the load current will be held depends upon (1) the average slope of the sensitivity curve (in the operating range), (2) the magnitude of signal current (to the second amplifier) at rated load, and (3) the power-system constants E_{do}, D, Y, and the rectifier ceiling voltage at rated load.

Recalibration of Constant-current Regulator

It is often desirable to recalibrate the regulator to hold load current values less than the rated rectifier current. This is an operating requirement in many continuous-process applications. The rectifier itself is not phase controlled over a wide range in these applications, because of the reduction in power factor. A tap changing supply transformer is generally used to provide large steps of load current adjustment under load.

When this is done, it is necessary to recalibrate the first magnetic amplifier as indicated in Fig. 4. The applied recalibrating signal compensates the first amplifier for the loss in signal from the d-c shunt at reduced rectifier loadings. With this method, the phase-control range of the rectifier is not altered, and it is not ne sary to calibrate the regulating system every time base load is changed.

Regulating Performance

The performance of power-rectifier regulators usually expressed in terms of accuracy and time response. The amplistat reactor itself responds v rapidly to sudden changes in signal. The actual respo time depends on the electrical constants of the p ticular amplistat, and also on whatever inertia effe there may be in the rectifier load. The over-all respo time of these regulators is in the range of ¼ to ¾ neglecting inertia effects in the load.

Regulators for standard industrial power rectif are designed to regulate the voltage, or current, wit

REGULATING PERFORMANCE RELATIONS

Power-rectifier Circuit Relations

E_{do} = No-load voltage

E_{dn} = Regulated voltage

X = Inherent regulation of rectifier and pow system, at rated load and rated supply volt in percent E_{do}, or per unit E_{do}

Ceiling volts at rated load $= E_{do}\ (1-X)$

$X = E_a + E_r + E_x$

D_o = System voltage fluctuations in percent (or D)

$$E_{dn} = E_{do}[1-(X+D)] \qquad \frac{E_{dn}}{E_d} = 1-(X+$$

Constant-voltage Regulators

X_R = Regulating accuracy in percent E_{dn}

$$X_R = \frac{X}{1+\left(\frac{\Delta E}{\Delta I_s}\right)\left(\frac{I_s}{E_{dn}/E_{do}}\right)} \bullet E_{do}/E_{dn}$$

$$\frac{\Delta E}{\Delta I_s} = \frac{\text{Per unit change in } E_{do}}{\text{Per unit change in } I_s} = \text{Slope of regulato sensitivity curve}$$

I_s = Per unit amperes, d-c bus signal, at $E=$

Constant-current Regulators

Y = Load current fluctuations in percent rat load current.

Y_R = Regulating accuracy in percent rated lo current.

$$Y_R = \frac{Y}{1+\left(\frac{Y}{\Delta I_s}\right)\left(\frac{I_s}{1.0}\right)}$$

$$\frac{Y}{\Delta I_s} = \frac{\text{Per unit change in rated load}}{\text{Per unit change in } I_s}$$

I_s = Per unit amperes, d-c bus signal, at $I=$ percent rated load current

Fig. 12. Regulating performance relations

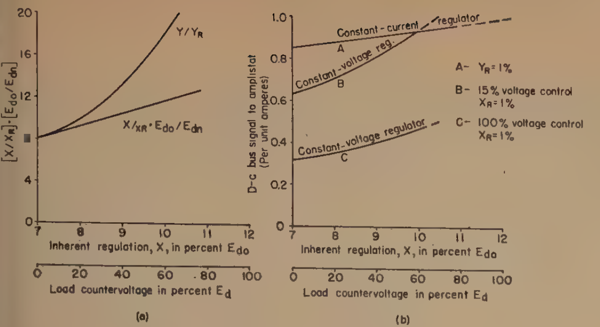


Fig. 13. Regulator design factors

percent of the rated value at rated load. This racy is determined when the rectifier is operated at al a-c supply voltage and frequency, and at rated ut voltage or current. Amplistats for special fier applications are designed by taking into con- ation the performance required and the constants e particular rectifier. One method for doing this is n in the Appendix.

mary

e amplistat regulator is a reliable device in in- rial power rectifier equipment. It is being applied creasing numbers in industry because of its low tenance and simple installation. A few signal cir- adjustments are all that are required to place it in ation. The electrical characteristics remain essen- y constant, and the regulating system, in general, ects for any small amount of drift which might r. The amplistat is well suited to many types of fier voltage control, other than regulation. Its d response and its ability to accept several indica- s simultaneously make it a valuable device in fiers used for specialized applications.

APPENDIX

rmining Regulating Accuracy

he rectifier power circuit constants, which are dia- mmed in Fig. 2, may be used to determine the regu- ng accuracy. The expressions for computing the accuracy are shown in Fig. 12. The no-load voltage of the rectifier E_{do} and the rated load current are the base values used in the per unit calculation. The numerical values of the power circuit constants are illustrated graphically in Figs. 5 and 9.

The principal power circuit constant, which affects accuracy, is the value of the inherent regulation of the rectifier and power system. The value of regulation is usually taken at rated load, except in special cases. The ratio between the rated voltage and the no-load voltage of the rectifier is also a factor. If all of the system constants of a particular installation are known, the regulating accuracy can be determined by using the equations in Fig. 12. If the equations in Fig. 12 are rearranged to show the ratio between the unregulated and the regulated changes in rectifier output, the resulting expressions give the regulator sensitivity which is required. These ratios, for both voltages and current regulators are plotted in Fig. 13(a). The principal power circuit factor which affects the accuracy of the voltage regulator is the inherent regulation X. The principal factor which affects the accuracy of the current regulator is the value of cemf in the load. These values are used as the abscissa in Fig. 13(a).

The curves in Fig. 13(b) show the variation in the d-c bus signal applied to the amplistat plotted against the principal power-system constant. These curves are for the regulating systems shown in Figs. 6, 7, and 10. The curves in Fig. 14 show the relative sensitivity of the power rectifier itself when regulating current or voltage. These curves show the change in voltage per degree of ignitor phase shift for the voltage regulator, and the change in load current per degree of ignitor phase shift for the current regulator.

Figs. 12, 13, 14, and 15 show the basic differences between constant-voltage and constant-current regulators for power rectifiers.

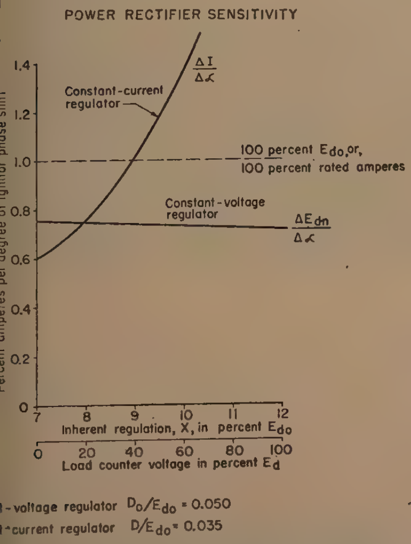


Fig. 14. Power rectifier sensitivity

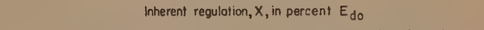


Fig. 15. Ratio of regulated voltage to no-load voltage

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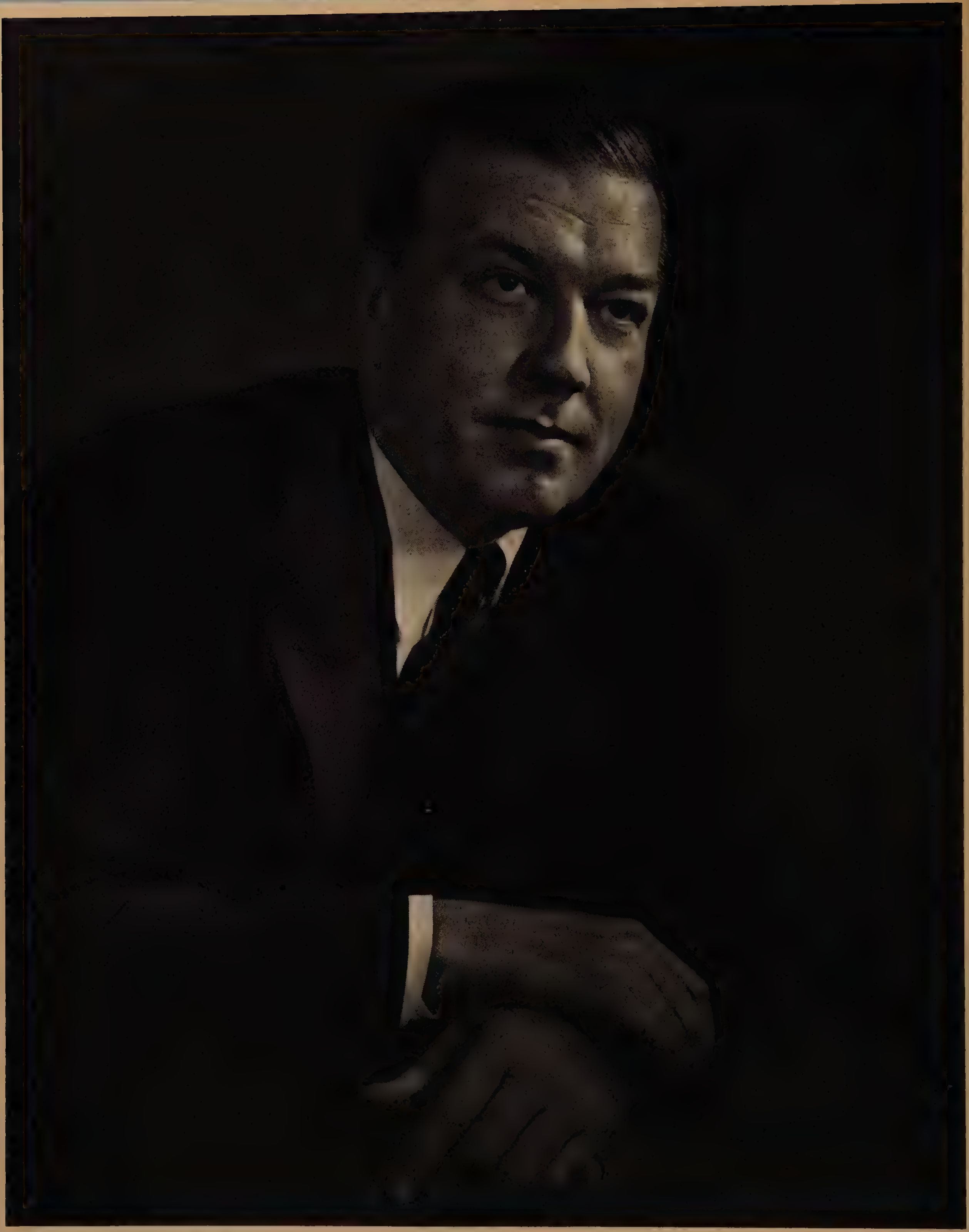

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ROBERT S. PEARE

Born January 11, 1901
Died March 18, 1951

ROBERT S. PEARE ★ AN APPRECIATION

Robert S. Peare, vice president of the General Electric Company in charge of public relations and advertising policy, died Sunday evening, March 18, 1951, after a short illness.

Although he was not an engineer himself, few men have seen more clearly than Bob Peare the great role of engineers and scientists in our time. He paid them tribute on many occasions, but above and beyond that he was a faithful reminder of their grave responsibilities. For this reason we reprint here a typical address, one that he gave to the American Institute of Electrical Engineers at their Fall General Meeting in Cincinnati, Ohio, October 18, 1949.—*Editor*

E UNSEEN THINGS IN YOUR PRODUCTS

IRST OF ALL, gentlemen, let me say to you that I am deeply sensible of the compliment you have l me by asking me to come here today. Because I e spent all but a few months of my adult life in the ploy of a company at the core of which is a group utstanding electrical engineers, I can appraise the pliment for its true worth better than one who has had that experience.

harge to the Engineering Profession

s first an accountant, then statistician, printer, ad- ising man, and finally public relations man, it has n my duty and pleasure to serve and sell a profession t has done more than any other in this period, or like period in recorded history, to give man the tools provide more material comforts and the time for ught to improve his spiritual and moral position. if I should say nice things about you today, please erstand that the feeling which prompts them comes n long association with men who make up your nbership, knowledge of what your leaders have been ng to do, and a firm conviction that you have the acities to do far more even than you have accom- hed in the past.

'orgive me, too, if this feeling and conviction leads to charge you with somewhat greater responsibili- than you had thought to be yours. Please bear in d that I have some knowledge through experience, not from a dictionary definition, of how much and t kind of responsibility members of your profession prepared mentally to accept. Such an organization 'ours is designed primarily to function in the public rest, and you and this public interest are what I t to talk about today.

ress Goods

am reminded again by your program of how much ut into the products of American industry that is not seen by the general public and that would not be understood even if it were seen.

Management is unseen.
Engineering is unseen.
Quality is unseen.

One cannot measure these things by the engineer's conventional methods or put them in the accountant's balance sheet. Yet they are real, they exist, and they are a very important part of the American scene. Otherwise, they would not be taken on faith by such a large segment of the American people. One in my position should be among the last to question the effectiveness of advertising; consequently, please don't think I am selling you down the river when I say that advertising must be backed to the fullest possible extent by integrity of purpose and integrity of performance if it is to win and hold public acceptance. I mean that there is something else besides good design and quality materials and skilled workmanship that goes into your products. That something else is an idea—an idea of which a society such as ours is particularly the custodian. My first thought is to say that it is the idea of progress, but I think that it is more than that. The idea is really progress itself.

The economists have a word for that proportion of the gross national product which goes not into things that are used or consumed instantly, but which goes into plants and into laboratories to provide more and better goods for more people at less cost *tomorrow*. The word they sometimes use for this is "progress goods," and from the proportion of the national product that goes into these so-called progress goods, they derive certain theories about the health and growth of a nation's economy.

It seems to me that we have a pretty good analogy here. The ideas of people like you, and the incentives to carry them out (for neither half of this equation is any good without the other), are the progress goods of our economic, social, and scientific world.

Restore People's Faith in Progress

While talking about some of the unseen things in your products a moment ago I said that although people cannot test products for these things themselves, they had learned to take them on faith. The main idea, and its part, however, is not only little understood but people are beginning to lose faith in the whole idea of progress itself.

There are many signs of this on every hand—the growing emphasis upon security, and the trend toward the welfare state. All this might not be too much cause for alarm if it were, as some insist it is, merely a sign that we are becoming predominantly a society of older people. Unfortunately, this kind of thinking is not safely confined to one group or one class; it pervades American life and thought today from the cradle to the grave. "In the electrical industry alone, we need an additional 150,000 young men who will go out and ring doorbells," says Jim Nance, president of Hotpoint, "but the trouble is that we didn't make salesmanship a profession, and a lot of young men today don't want to take a chance." It must be an appalling thing to be young in an age which doubts progress.

Now, isn't this an awful perversion when this faith of the public in your character, your skills, and your purpose, built up so painstakingly over something like a half century, can be used, by men who have none of these attributes, to sell unproved and unprovable ideas? Doesn't the fact that it is happening show us that there is at least one prime ingredient missing?

It would be too bad if at this hour and this date we should lose this main chance for the world. For it is this progress that has been our great contribution. I think it was F. Scott Fitzgerald who once wrote "France is a land, and England is a people, but America has about it, above all, the quality of an idea." Perhaps this has been our great opportunity—more so even than our frontier, or our natural resources, admittedly great advantages that they were. For the land can change only slowly, and a people almost as slowly, in synchronization with some geologic or racial time clock. But ideas are revolutionary rather than evolutionary where time and change are concerned. And it may be that this quality of the idea, specifically the idea of progress, is the primary reason why we are several steps ahead of the people of any other nation in mass education, production, health, and standards of living.

Defend Avenues for Initiative and Achievement

Of course progress still exists. This meeting is testimony to that fact. But our faith in progress has suffered some severe setbacks in the past generation and the past few decades. It has been fashionable in some circles to decry our progress as mere materialism; even thoughtful people have in recent times been openly wondering if we should not prune the tree of knowledge.

But it is not those who would lop off the whole new branch of atomic science, or any other, who spell the real danger, but rather the more insidious who would deplete the soil in which progress grows. It is the erosion
of the human spirit, the loss in incentives and a ba
optimism about tomorrow—whether in terms of a b
ter way or a better day—that is going on all over
world on a vast scale under centralization and collecti
zation.

The second law of thermodynamics is in effect a dea
sentence, although without a time limit, on our physi
world. For it states that in a closed system the entro
can only increase, or at least remain constant, but
never decrease. Thus the high-grade energy available
work must inevitably become less, and be transform
into inutile low-grade energy. This principle of ener
degradation means, apparently, that our universe
running down.

Similarly, in the world of men, collectivization i
death sentence, also without a time limit. It means th
in any such closed system the entropy of human en
gies, and their transformation from a high-grade t
low-grade form, can only increase, or at least rem
constant. The entropy of the system can never be
creased, or the process of the gradual degradation of
human energies reversed, by even the hardest pull
the collectivist bootstraps.

One of the shrewdest guesses about a collectiv
future is contained in George Orwell's book, *1984*.
like the utopias of H. G. Wells and Aldous Huxley, w
foresaw an increasingly rapid rate of advance for scie
and technology, Orwell foretells a world in wh
science and invention are running down, as well as
human spirit. As indeed they must, for these things
more closely interlinked than many people understa

It is no accident, I believe, that we find in a soci
such as this one, men still holding firmly to the idea
progress and devoting their lives to it. It has been
peculiar bias of our society, and I think our great g
fortune, that most of our creative minds and act
personalities go into engineering, or the sciences,
into industry. And, by and large, it is not the mon
making possibilities that attract them, but the opp
tunities for creative achievement.

Contribute Dynamic Ideas

Moreover, your greatest contributions have proba
not been in the tangible symbols of great enterpr
though these have been conspicuous, but in terms
ideas. The contribution of ideas cannot be measured
a chart, or even by the production of professio
papers; yet, according to an estimate by Herbert
Northrup in an article in the *Harvard Business Revi*
regarding professional employees, ideas are usu
more valuable than a 50-percent increase in prod
tivity per man. And Kipling once wrote of the relat
of things to ideas in another form:

> "If England was what England seems,
> And not the England of our dreams,
> But only putty, brass, an' paint
> 'Ow quick we'd drop 'er! But she ain't."

Enlighten Society with Your Purpose

All of this suggests an important role today fo
society like this one. And I think this is the miss

he ingredient I mentioned a few moments ago. In Dark Ages, when the barbarian hordes swept over ope, the monasteries became the refuge of learning, thus was preserved much of the culture and knowl- which we have inherited. Is it too fanciful to sug- that the function of a society like this is somewhat llel, when men are succumbing to cynicism and air, and losing faith in what is in the last analysis r own abilities, so that the gates are opened every- re to the monomaniacs, and the egomaniacs?

am not suggesting for one moment that you with- v from the world and become monks. I'm suggesting exact opposite—an age of even greater light. One l of sermon that the world badly needs today is from like you who can define their function in society—as- ations like this help you to define it, I think—and can help to plot the conditions that will keep the ls of progress and productivity open. We may not w all these conditions—we could do with a few more ch marks—but we do know that we have a system in America that has produced the goods, and we w that experiments in other directions in other ntries to date have turned into dead-end streets. I not promoting technocracy, which seemed to me to mise only a spiritless age of specifications.

ngthen and Keep Our System Working

believe it is your first responsibility as individuals as an association to make the system work, to keep roductive and strong, for it is the great role of men you today to keep the wheels of America and the ld turning. Let's not forget the Communist monkey nches, and let's be on guard against them. But let's get so occupied in watching for these that they dis- t us from the main job, for the Communists cannot except by default. They know that as well as we do. nce, the policy of distraction.

s Walter Lippman says, "Free and civilized men not quiver and quake forever about Communism or nd their days doing nothing better than to listen to nors about what the Politburo and the Cominform are to next, or degrade themselves in witch-hunting and orbid concern with the demonology of Moscow. Nor they live forever and exclusively on the calculations dollar deficits, and predictions about long-range nbers and atomic bombs, and resounding declarations ut how much better liberty is than tyranny. They d also great constructive ideas in projects which st their energies and give meaning to their lives."

rify and Uphold the Role of Business

would not be selfish *enough* if I did not think, too, t on those who make the wheels go around there is responsibility of keeping the public and our legis- rs informed about what makes the system go. How ny of those engaged in economic planning, or how ny members of Congress, know that there are limits he amount of planning from above which a civilized ety can bear without a loss of vital initiative; al- ugh, if they had read enough of the history of the r Roman Empire and the efforts of Diocletian to e economics by state planning, they might know this.

The Department of the Interior wasn't sitting up with Edison at Menlo Park 70 years ago watching an absurd filament glow in a bottle. The House Small Business Committee wasn't working side by side with the men in the business through the heart-breaking disappointments of the early lighting plants, the diabolical brush failures on the first transit systems. The Treasury didn't put up any money to see an infant industry through great financial panics. There were no floods to be controlled at Menlo Park, or in Lynn, or Fort Wayne. The truth is simply that no government is omnipotent enough or omnipresent enough to take care of things like this. They must be taken care of, as they have been, by people like you on their own.

Government, like all noncreative segments, can only share in the benefits, or profits, or increased productivity when these are created. And it is unfortunately the tendency of all governments, from the time of the Romans down, to harvest crops that should be plowed back into the soil.

There is a responsibility for people like you in helping Americans to really think about and understand business. Much of the so-called thinking and writing about business today is a mouthing-over of Marxian theories, Communist catchwords, and political wishing. And, the literature of American business is at least 50 years out of date. Business, you know, is just people working together.

Participate in Selling Our Kind of Society

But above all, I believe that it is the responsibility of men like you to be salesmen for your kind of society. You may object that you just wanted to be a good engineer, but it is doubtful if being only a good man in your particular profession is a luxury that any country today can long afford, for the plain truth of the matter is that our kind of society is being out-sold by an inferior product in many parts of the world. Perhaps a part of the Communists' former success is due to their employing certain *improved* sales techniques, such as the cell block and the firing squad, but the fact remains that we are being out-sold, and sometimes right on our own doorstep, too.

Assist in Solving the Problems of Our Time

The competition between ideas is stiff today, and it's going to get stiffer. This follows, as the night the day, improved methods of communication.

We don't know too much yet, although we know more than we did even a few years ago, about why certain ideas gain acceptance and have influence and others do not. Sumner Slichter suggests that "Many ideas gain influence, because they *are* supported by evidence, or because they *seem* to promise solution to important and baffling problems. Ideas appear to be particularly influential if they relate to problems which concern a large part of the community. Furthermore, ideas gain influence when they are positive rather than negative. If the community has a difficult and persistent problem and wishes to do something about it—

the people who have the most influence upon events are those who are willing to propose solutions."

I repeat Mr. Slichter's words, "The people who have most influence upon events are those who are willing to propose solutions." I think you fit that specification better than anyone I know. Solution of problems is your business.

And where do you start to solve those problems? The answer was given by Russell H. Conwell in his *Acres of Diamonds*. Right in your own back yards, your homes and your plants, with your associates and your employees, the teachers of your youngsters or your grandchildren. That is where you exert your maximum leverage. An association such as this has an important place in every profession—it helps us to raise our sights, to collaborate on problems, to contribute solutions. But in the last analysis it is at home, in your own communities, in your own businesses, that you really move the world, if it is moved. There, personal honesty, open-mindedness, focussed vision, and love of truth have their main chance. There, as Herbert Hoover reminds us in a recent speech, phrases and slogans can be dissolved in common sense and integrity. There, the people who are engineering fuzzy-minded compromises can be shown up for what they are.

Preserve Human Liberty and Opportunity

The structure of "the good society" is raised fro the family unit and community. Good governme grows naturally from the good community. But t process cannot be reversed. The planners cannot crea a community any more than they can create the liv of those who live in it. All that can be provided fro the top is a collective mold into which that avera figment of the planner's imagination, "the comm man," is crammed, trimmed, punished, until he co forms to the mold or is figuratively or literally dea The entropy, as we have said, of such superimpose systems has proved appalling.

Given space and chance, the lives of ordinary Amer cans fall into reasonably orderly, pleasant, and pr ductive patterns. That space and chance is bei dangerously encroached upon today in many areas. is the manifest duty of everyone here to help erect " trespassing" signs at these points, against governmen as against any other trespasser of human liberty a opportunity. There *is* something sacred to the futur an idea of progress and a better way, naively optimist and American perhaps, but nevertheless one which our time spells almost the only gleam of hope for t humanity of the world.

The Grand Coulee Dam is the principal engineering structure of the Columbia Basin irrigation and power project in central Washington. It is 4173 ft long, 550 ft high above lowest bedrock, 500 ft wide at the base, and contains about ten and a half million yards of concrete. The spillway waterfall is half as wide and twice as high as Niagara. The dam raises the water of the Columbia River 350 ft toward the irrigable land, and provides power for the pumping of water and for commercial uses

ORLD'S LARGEST MOTORS DRIVE WORLD'S LARGEST PUMPS

billion gallons a day per pump in the world's largest water- —for irrigation in the Columbia Basin Project—requires the tallation of 65,000-hp electric motor drive for each pump

By MAJOR S. E. HUTTON
Information Officer, Bureau of Reclamation
Coulee Dam, Washington

SEHutton

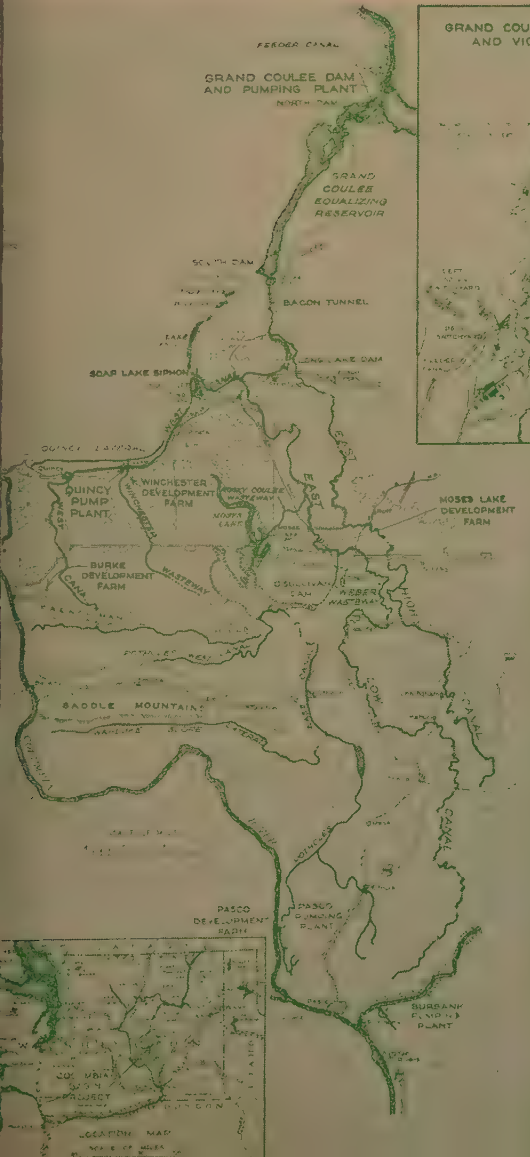
HE necessity of lifting water 280 ft out of the Columbia River Canyon, at the ultimate rate of tons a second, accounts for the installation of the ld's largest pumps and most powerful synchronous ors, at the Grand Coulee Dam.

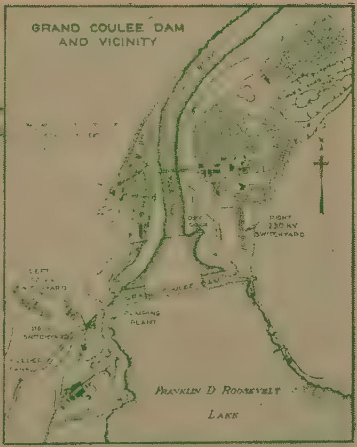
t full capacity, each pump will deliver more than a on gallons of water a day—enough for the people New York City. Each pump will be driven by a 00-hp motor.

ositions were provided for twelve pumps when the n and the base for the pumping plant were built. It xpected that ten pumps will meet the water requirets of the 1,029,000 acres that are ultimately to be gated on the Columbia Basin Project in central Washington. Ten pumps will deliver a stream of water almost equal to the average flow of the Colorado River at the Hoover Dam.

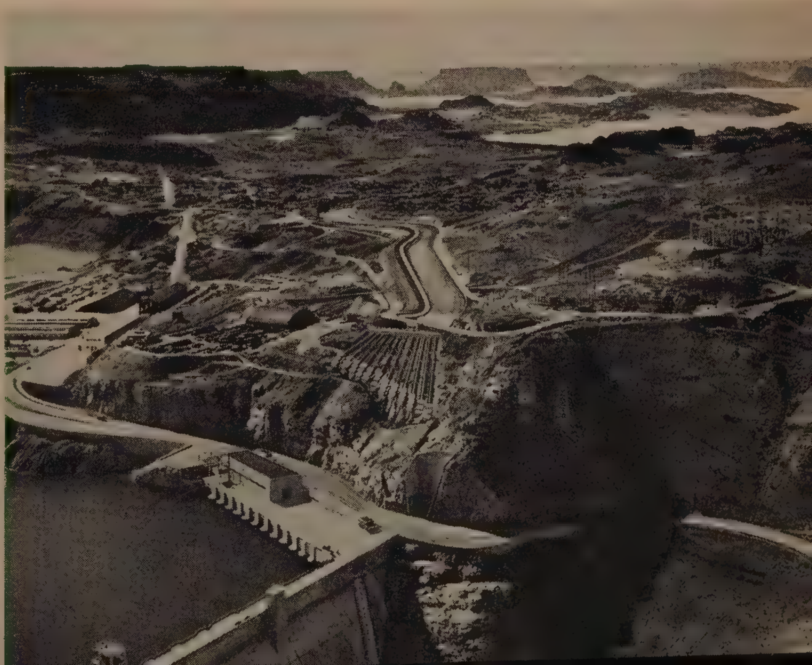
Six pumps, with their motors and control equipment, are under installation now, and the first is to go into service early in May 1951. During the summer, all canals, tunnels, siphons, and water-control devices in the water distributing system will be tested, canal banks will be primed, and all necessary preparations will be made for delivering, in the spring of 1952, water for the first 87,000 acres of land to be irrigated.

Central Washington is one of the very few localities in the semiarid far west where the water supply exceeds the capacity of adjacent dry land to absorb most of it





The Columbia Basin Project. These three maps show the region that will be irrigated, the irrigation system, and the immediate vicinity of the dam and the pumping plant



In this aerial view of the dam and the Upper Grand Coulee, an artist has shown the pumping plant and, at its right, the 12-ft pump outlet pipes through which water will be lifted 280 ft into the feeder canal, and a part of the equalizing reservoir

Grand Coulee powerhouse interior. In each of the two powerhouses, at opposite sides of the spillway, nine generating units have been installed. Over long periods, they have carried continuous loads of 125,000 to 130,000 kw. The first six generators in the left powerhouse are to furnish power for pumping water for irrigation. They have motor-driven exciters, so that they can start with excited fields and thus start the 65,000-hp pump motors

in irrigation works, but it is one of the latest areas to be irrigated. The reason is that the great water supply is in the upper Columbia River, which flows in a canyon about 1600 ft deep, from 60 to 150 miles from the irrigable land.

To put water on the land, it is necessary to lift it 630 ft into the Grand Coulee, the diversion channel of the Columbia River's ice-age ancestor, and to carry it about 60 miles, in canals, tunnels, and inverted siphons, to the edge of the irrigable area. The Grand Coulee Dam has created a 150-mile reservoir, with a surface normally about 350 ft above the river level. The remaining lift of 280 ft is to be made by the new pumping plant.

Irrigation, alone, would not repay the tremendous cost of the dam, the pumping plant, and the great canal system. Development was necessarily delayed until the need for power and other public benefits made the project feasible. With 15 of the ultimate 18 generators in service, the power output has already exceeded 44,000,000 kwh per day, with a high hour above 1,900,000 kw.

Water for irrigation purposes, and power to lift it up into the Grand Coulee, will come from summer surpluses. The Columbia is unique in having its flood season in the summer, when warm weather releases water from the snow and ice fields of the Canadian Rockies. Only one twentieth to one tenth of the summer flow will be diverted for use in irrigation. Also, during the summer, the power demands from other members of the five-state Northwest Power Pool is least. Much of the pumping will be done off-peak.

Power for Pumping

Six of the nine large generators in the left powerhouse were designed for pumping duty. They differ from others only in having motor-driven instead of the conventional built-in exciters. The 60-cycle 13,800-volt generators are rated 108,000 kw, but have carried loads in excess of 125,000 kw. Under varying conditions of high tailwater and reservoir drawdown, the ge erator capacity will vary between 80,000 and 130,0 kw. The capacity will be 120,000 kw or more duri most of the pumping period. The Westinghouse gene ators are driven at 120 rpm by Newport News Franci type turbines, under control of Woodward governor

Buses to Pumping Plant

Normally, the generators are connected to the 230,000-volt transformers through isolated-phase bus provided with disconnecting switches. A second set similar buses, with disconnecting switches near th generators, extends from generators through a galler in the powerhouse, thence up the face of the dam, an through it, to the pumping plant.

The Motors

The first two pump motors to be installed were bui by the General Electric Company. They are rate 65,000 hp at unity power factor, 3-phase, 60-cycl 13,600 volts, 200 rpm. Additional motors are being bui by Westinghouse. They are attached by rigid flang couplings to the vertical-shaft pumps. The rotors a equipped with amortisseur windings which perm starting the motors as induction motors.

The upper motor bracket carries one guide bearin and the thrust bearing, supporting the weight of a rotating parts and the unbalanced hydraulic thrust o the pump impeller. On the lower motor bracket is second guide bearing and the rotor brakes.

Thrust Bearing

The thrust bearing is the General Electric sprin type with smooth runner and segmental babbitte stationary plates. The bearings are unusual in that pr vision is made to introduce high-pressure oil in the cent of the stationary segments to establish an oil film b tween the bearing surfaces before the motor is starte This arrangement greatly reduces motor bearing frictio at starting and so reduces to a minimum the mot starting torque which must be developed electrically.

Brakes on Motors

Each motor is provided with air-operated brak which can be used also as hydraulic jacks to lift th rotating parts of motor and pump for the purpose removing or adjusting the thrust bearing.

The brakes are designed to bring the rotating par to rest, from 100 rpm, within 5 min. The control syste automatically prevents the application of the brak above half normal motor speed. The brakes are to applied only 3 or 4 sec in 10-sec periods.

When a pump is being shut down, the motor spe diminishes to zero; then the pump becomes a turbin driven in reverse by the water draining out of its outl pipe. The brakes are applied only after the motor h again slowed down at least to half speed.

Cooling

The pump-plant motors, like the generators in t powerhouse, are cooled with water from the reservo r is forced through openings in the shell of the r into the air chamber surrounding it, by the ction of the rotor, the air is cooled by the eight exchangers placed over the openings. Water at or less, keeps the cooling air entering the motor 40 C.

in the thrust bearing reservoir is cooled by water ating in a copper coil submerged in it.

erature Indicators

the control board for each unit is a selector switch n enables the operator to take temperature readat two points in the bearing metal of the thrust ng, at one point in each guide bearing, and at ten s in the stator windings. Two other resistance erature devices in the stator windings are coned to thermal protective relays.

ercury thermometers show the temperatures of oil e bearing reservoirs and the cooling water.

peed Protection

e of the two overspeed switches installed on the r end of the motor shaft is connected to the aniator on the control board. The other is connected protective relay. Both are set slightly above the mum reverse overspeed reached when a pump is down.

ing the Motors

o pump motors are to be driven from one genr with a nameplate rating of 108,000 kw, but able rry loads in excess of 120,000 kw when the head of the turbines is high. Both the six generators that are to be used in pumping service and the pump motors are provided with motor-driven exciters so that fields can be excited independently of generator and motor speeds.

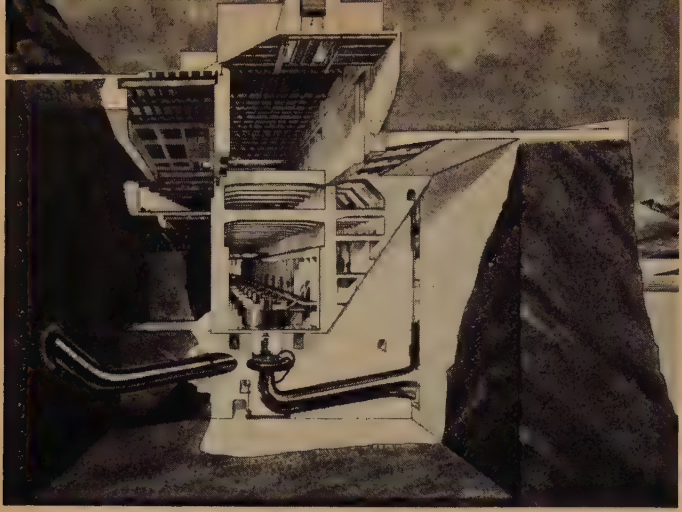
Before the generating units and the pump motors are started the exciters of both generators and motors are running at normal speed, and are in closed circuits with the fields of their respective units. Pilot exciters are developing normal voltage, but the field circuits of the main exciters are open.

The pump motors can be started as synchronous motors or as induction motors, the essential difference between the two methods being that, in the latter case, motor-field excitation is not applied until the motors are synchronized with the generator. In both methods of starting, the rheostats in the fields of the generator's and motor's main exciters are preadjusted to the best positions for starting.

To start a pump motor as a synchronous machine, the generator, at rest, is connected to the 13,800-volt buses leading to the pump motor; field circuits of both generator and motors are closed; exciters are running at normal speeds; and pilot exciters are developing normal voltage; but the field circuits of both exciters are open. The rheostats in the fields of the exciters of generator and motor have been adjusted to proper position. The circuit breakers of the pump motors and those of the main exciter fields are then closed. The turbine gates are opened and the motor comes up to 60-cycle speed in step with the generator.

n the pumping plant base, provisions for the installation of 12 large umps were made when the Grand Coulee Dam was built. A gravityype dam, 612 ft long and 160 ft high, was built at the west abutment, fter 18-ft tunnels for the future installation of 12-ft outlet pipes had een driven up through the abutment. Inlet pipes were embedded in the ing dam, their inner ends closed with hemispherical bulkheads

Buses to pump motors. Power is furnished to the 65,000-hp motors at 13,800 volts, through hollow, rigid conductors supported on radial insulators and inclosed in nonmagnetic jackets. From the generators, they traverse a large gallery to the end of the powerhouse, and then follow an inclined plane on the face of the dam to an opening at the end of the pumping plant



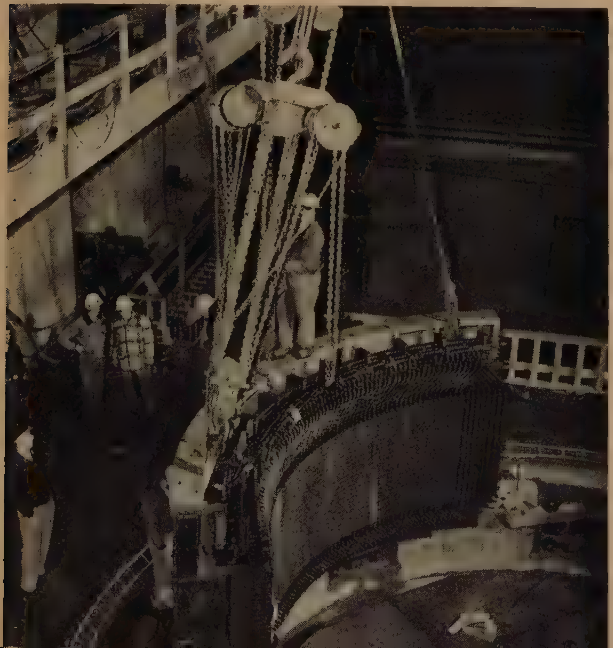
Sectional view of Grand Coulee pumping plant

To start a pump motor as an induction machine, the turbine gates are adjusted so that the generator is run at about 70 percent of its normal speed with its field circuit open, while the motors, with open field circuits, are at rest, and not connected to the generator. The exciters of both generator and motors are running at normal speeds, but the field of the generator exciter and the circuit breakers in the motor fields are open.

A control switch in the turbine-governor cabinet is closed to start the motors. The rheostats in the fields of the generator and motor exciters are set in proper positions for starting. The motor circuit breaker and the field of the generator exciter are then closed. As the accelerating motors and the decelerating generator approach synchronism, the motor fields will be closed. After the synchronizing of the generator and motors, the turbine gates, which were left at initial setting during the starting period, are opened to bring the units to normal speeds.

Since it causes less shock to the generating and pumping units, the synchronous method of starting will be used ordinarily. If a quicker start is required, the induction method will be used.

The generators driving pump motors may be connected to the station's 230,000-volt buses and synchronized to deliver surplus power when pumping conditions are favorable, or to receive power from system during periods of low head on the turbines.



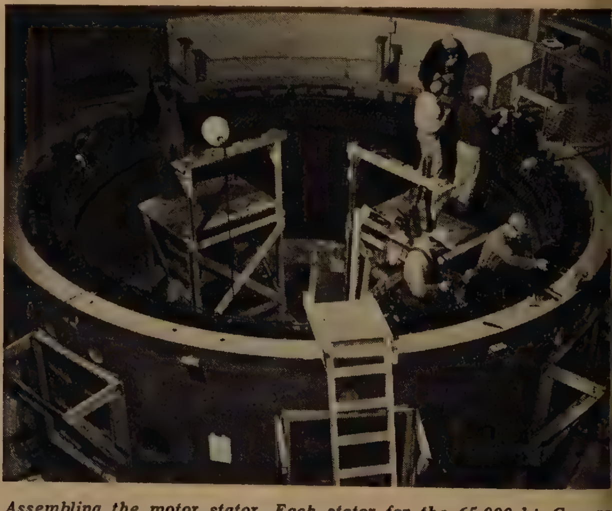
If a generator in pumping service is not connect to the station buses, pumps may be stopped by clos the turbine gates and allowing generator and motors slow down together. If it becomes necessary to st pumps while the generator driving them is connect to the station buses, the turbine gates will be adjust to minimize overspeed and power surges before t motor circuit breakers are opened.

The Pumping Problem

Water is to be lifted from the Franklin D. Roosev Lake, the 151-mile reservoir which extends from t dam to the Canadian boundary, to a canal and reserv in the Upper Grand Coulee. Including friction hea the lift may vary from 365 ft to 270 ft. Most of t pumping will be done at the minimum head. T ultimate maximum water requirement is expected be about four and a half million acre-feet, and percent of the demand may occur in one month.

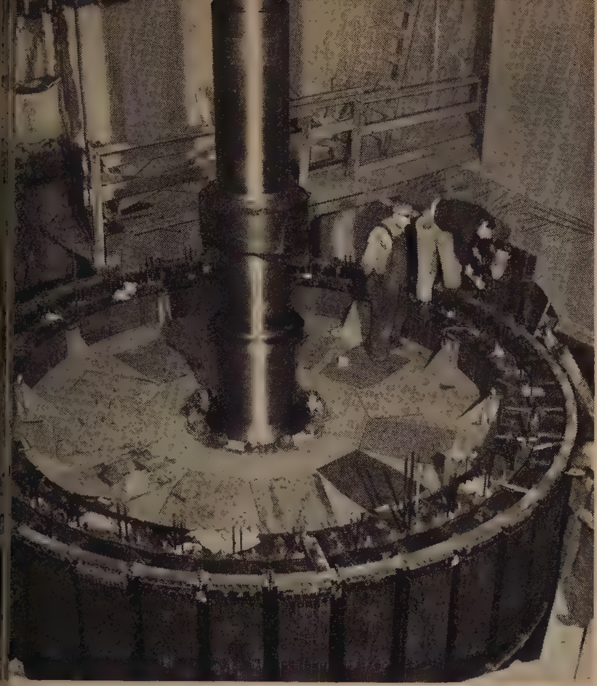
Whenever there is a water supply at the dam in e cess of the requirements for power generation—that during the summer months—the surface of La Roosevelt is at Elevation 1290 above sea level. Duri the winter, the reservoir may be drawn down, f power production, to Elevation 1208. Depending up the rate of pumping, the surface elevation in the feed canal will vary between 1553.5 and 1570. These va ations account for the range of pumping heads.

Since the winter and early spring flow in the river ordinarily not sufficient to carry a full power load f time, water will not be available from the river for ear spring irrigation. Fortunately, the equalizing reservoir the Upper Grand Coulee has a live storage capacity 700,000 acre-ft, and water carried over from one summe surplus can be used to start irrigation the next spring.



Assembling the motor stator. Each stator for the 65,000-hp Genera Electric synchronous motors was shipped from the factory in four sec tions, and was set on a base over the pump, made by embedding stee blocks in the hollow concrete pier which supports the motor and enclose the shaft connecting the motor and the pump impeller. The windin was completed after the stator was in its permanent position.

The 13,800-volt power supply enters from the right. Parts of the ai chamber around the motor are shown in place, and brackets to suppor heat exchangers can be seen in the foreground



ors were assembled in an unoccupied pump pit by General Electric
ws made up in part of factory and field men and in part of local
ftsmen who have had as much as ten years experience installing
removing big generators. Two 75,000-kw G-E generators, built
Shasta, were used at Coulee Dam two and a half years during the
before being forwarded to their final destination. Sixty-five hundred
ds of reinforced concrete was quarried out of the left powerhouse
ecover the turbine scroll cases

nbling the pumps. The output
ch 65,000-hp motor is trans-
d through a 16-ft shaft to a single
impeller, fourteen feet in dia-
, running 200 rpm. The impeller
es its water supply through the
-and-a-half foot circular eye in
ttom and discharges it through a
inch speed ring in the pump's
scroll case. All parts of the
s except the scroll cases can be
l or removed through the motor
and the hollow pier below it.
cases are embedded in the con-
oundations of the pumping units

The Pumping Plant

While the main dam was under construction, 12 tunnels were driven into the granite abutment at the west end of the dam, and then diagonally upward, to accommodate steel pipes to be installed later. Then a gravity-type wing dam 160 ft high and 612 ft long was built parallel to the abutment and at an angle of 67 degrees with the dam. Inlet pipes 14 ft in diameter were embedded in the concrete, each closed at its exposed inner end with a hemispherical bulkhead, to be removed after a 13-by-20-ft rectangular roller gate was installed over the bell-mouth entrance, just prior to the installation of the corresponding pump. The pumps and their motors and controls are installed in a building between the wing dam and the abutment.

The Pumps

The single-stage, vertical-shaft pumps were designed and furnished by the Byron Jackson Company of Los Angeles and the Pelton Water Wheel Company of San Francisco, under a joint contract, and were built in the shops of the latter. They are rated 1350 cfs at 310 ft head, and expected to deliver 1600 cfs under a 280 ft head. The impeller is 13 ft, 11⅜ in. in diameter. An accelerating elbow joins the 14-ft intake pipe to the 7 ft 5¾-in. eye of the pump, and a 3-degree diffuser, 61 ft long, delivers water from the pump to the 12-ft outlet pipe leading to the feeder canal above the pumping plant.

The pumps are set on 45-ft centers, but the outlet pipes converge as they leave the pumps, and are on 14 ft, 6-in. centers at the top of the lift where they enter concrete siphons which terminate in rectangular openings 12 ft, 4 ½ in. wide and 16 ft, 5 in. high, at the enlarged and depressed end of the feeder canal. Thirty-inch siphon breakers are provided so that water will not be siphoned out of the canal when a pump stops.

The Equalizing Reservoir

The feeder canal, 50 ft wide at the bottom and 125 ft wide at the top, extends 1.7 miles from the pumping plant headworks to the 27,000-acre equalizing reservoir, in the Upper Grand Coulee. It is concrete-lined, and will carry 16,000 cfs.

Scroll cases for the pumps were made of welded steel plate and cast steel shrouds, each in two pieces. They were located accurately in position, on screw jacks set on concrete pedestals, and bolted together and tested before being embedded in the concrete foundation of the pumping unit

The North Dam consists of an impervious core of earth, moistened and compacted by tractor-drawn sheep-foot rollers, flanked with heavy deposits of semi-pervious materials, rock faced to prevent wind and wave erosion. It is 145 high, from lowest bedrock, and 1400 ft long.

The equalizing reservoir occupies the greater part of the floor of the Upper Grand Coulee. It will be 1 to 5 miles wide and 27 miles long. The total storage capacity is 1,202,000 acre-feet, and the reservoir will yield 700,000 acre-feet with a 15-ft drawdown. Its southern terminus is the South Dam, an earth-fill structure nearly 10,000 ft long, and with a maximum height of 120 ft above bedrock. It contains about a million and a half yards of fill material.

The equalizing reservoir cost less than 27 miles of concrete-lined canal would have cost, and it provides valuable water-storage space. It will serve as a surge tank between the pumping plant and the irrigation system, making it unnecessary to synchronize pumping with the water demand, and permitting pumping during off-peak periods. It will also carry over, from a hi water season of one year, a water supply for the ea spring irrigating of the following season.

Water Distributing System

From the equalizing reservoir, the water will carried southward through a system of canals, sipho tunnels, and control works to a million acres of semia sagebrush land and abandoned dry farms, in an a 65 miles wide, east and west, and 85 miles long, no and south. Among the more spectacular pieces of c struction in the water distributing system is the 10 ft Bacon siphon, a reinforced concrete pipe 23 ft in ameter, inside, with walls 23 in. thick, which cros an arm of the Lower Grand Coulee and discharges i the 10,000-ft Bacon Tunnel. These will carry wa sufficient for half a million acres of land. Later dup cates will be made, parallel to them.

An even larger siphon crosses the lower end of Lower Grand Coulee, to carry water to the nor western part of the irrigable area. The Soap La Siphon, 12,883 ft long, consists of reinforced concr sections at the ends, totaling 4631.74 ft, and a ste lined 8251.83-ft middle section, where the head reac 239 ft. Hundreds of miles of distributing canals a thousands of miles of laterals will ultimately deli water to 13,000 farms and many towns and villag

Design and Construction

This, the largest project yet undertaken by Bureau of Reclamation, was made possible, within life of that agency, by developments in the field of el trical engineering—high capacities, and the ext ordinary reliability of generating, transmission, contr protection, and application apparatus.

The Columbia Basin Project was designed by Bureau of Reclamation, of the Department of the terior and has been built under its supervision. Dur the period of construction, Raymond F. Walters, W ker Young, and L. N. McClellan were successiv chief engineer of the Bureau. John L. Savage was c designing engineer. Frank A. Banks was in charge of project from its beginning in 1933 until his retirem late in 1950, successively as construction engine supervising engineer, and district manager.

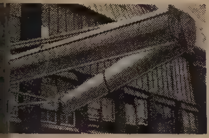
Soap Lake Siphon. Low places in the route of a canal are crossed by means of so-called inverted siphons—reinforced concrete pipes, some as much as 25-ft in diameter, inside, and under heads of 200 ft or more. The Soap Lake Siphon, a mile and a half long, crosses the lower end of the Lower Grand Coulee, above the mineral-charged Soap Lake. A part of it is lined with steel plate, rolled and welded into sections of 25-ft pipe, in a plant set up at the site

Large canals are lined with concrete. Special equipment, adjustable to canals of different depths and widths, is used to trim the compacted canal bank, place the concrete lining, finish joints and surfaces, and apply a curing compound. Two three-yard concrete mixers are kept in continuous operation on batched materials hauled in by high-speed trucks

UORESCENT STREET LIGHTING— WHY—WHEN—WHERE

A. F. Dickerson

Experience with installations in this country and abroad provides a basis for reconsidering our street lighting problems in terms of new levels of high-quality illumination



By A. F. DICKERSON

Lighting and Rectifier Divisions
General Electric Company, Lynn, Massachusetts

1945, three sample installations of fluorescent eet lighting for study purposes were made at it, at Cleveland near Nela Park, and within the al Electric Schenectady Works. The reflectors were for industrial indoor use and were not suited is outdoor application. The results obtained were clusive. They did, however, indicate that excellent lighting could be obtained with fluorescent s, although the economics involved at the time ed to favor our conventional filament and mercury- systems.

lations in Great Britain

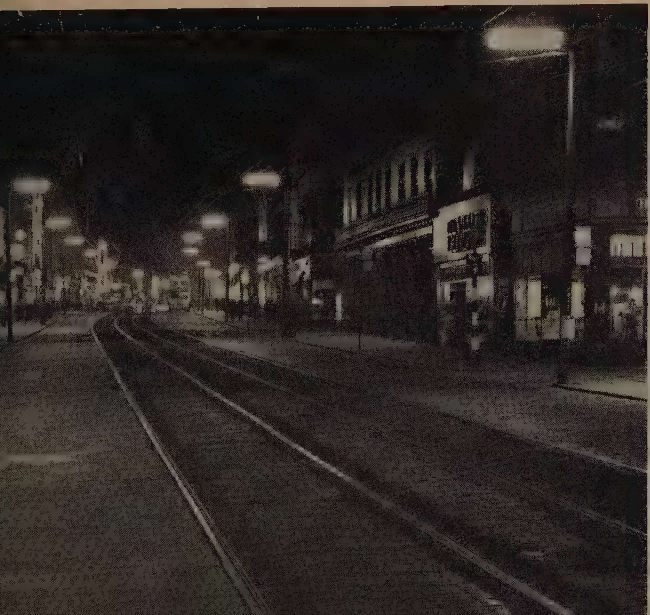
August 1, 1946, High Street in Rugby, England, ighted by the B.T.H. Company of England with aires equipped with fluorescent lamps. A few s later this same Company similarly lighted Bond t, London (FRONTISPIECE). These installations ed a widespread interest in this form of lighting in and which has gradually spread to many other tries, including our own.

e British pioneered the use of fluorescent street ing because of the excellence of the visibility and ver-all results obtained from luminaires correctly ned and engineered to apply fluorescent lamps to t lighting. The B.T.H. Company made lanterns to take three (and later two) 60-in. 80-watt lamps burning in a horizontal position, offering greatly improved night visibility without an increase in power usage. In spite of the advantages, including that of low current consumption, rapid expansion of the system was slowed by the comparatively high capital cost and Government restrictions on capital expenditure. Nowadays the quality of the results, the proved reliability of the lanterns, and the low current consumption are powerful factors for relaxations which are permitting more and more municipalities to set up installations.

To date there are in Great Britain over 60 fluorescent street-lighting installations of twelve lanterns or more (FIG. 1), the largest by B.T.H. employing 257 lanterns, and lighting practically all the principal streets of Rugby. These installations have all been successful, and many have been, or are being, extended.

Installations in the United States

In this country, the first engineered installation of fluorescent street lighting was lighted at the General Electric Company's River Works in Lynn, Massachusetts, in May, 1950 (FIG. 2). There, on Works Avenue, the lighting from six 280-watt double-reflector luminaires of a very efficient design can readily be compared with the illumination provided by six G-E Form 109



1. Great North Road, Newcastle-on-Tyne (England). Three-lamp escent units, with 80-watt 5-ft warm-white lamps are mounted on ing tram poles

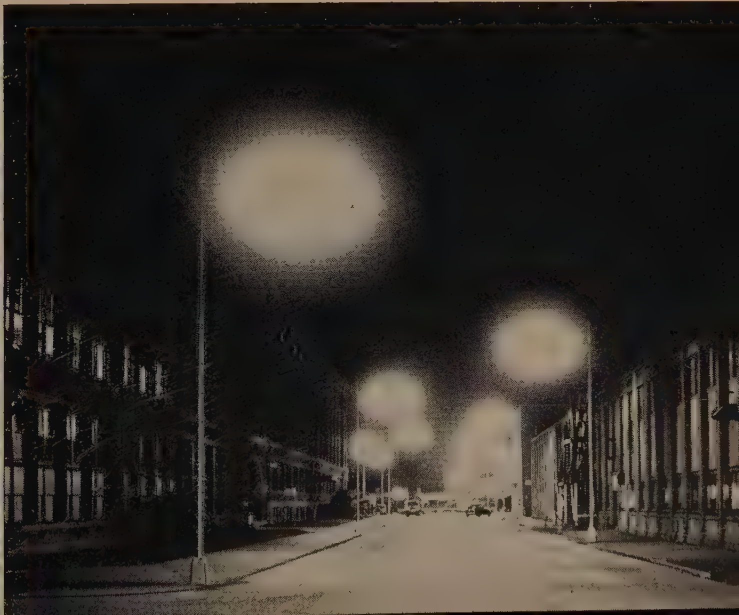


Fig. 2. Fluorescent luminaires along Works Avenue at Lynn (Mass.) are equipped with four 96-in. Slimline lamps

luminaires equipped with 400-watt mercury lamps. While the Form 109 might well be called the best designed and most efficient luminaire available today, the fluorescent installation, giving approximately the same average illumination, is generally conceded to be much better from almost every point of view.

The first U.S. municipally financed installation of fluorescent street lighting meeting the requirements of the American Standard Practice of Street Lighting was lighted in Detroit (Mich.) on November 3, 1950, using 24 Form 200 twin-reflector luminaires (Fig. 3). At Lynn, two 96-in. T8 Slimline instant-start lamps operating at 300 milliamperes are used in each reflector —four to the luminaire. Each lamp with ballast consumes 81 watts and emits 4150 lumens (16,600 per luminaire). At Detroit, each luminaire has four 96-in. T12 Slimline instant-start lamps, each operating at 600 milliamperes giving 5400 lumens (21,600 total).

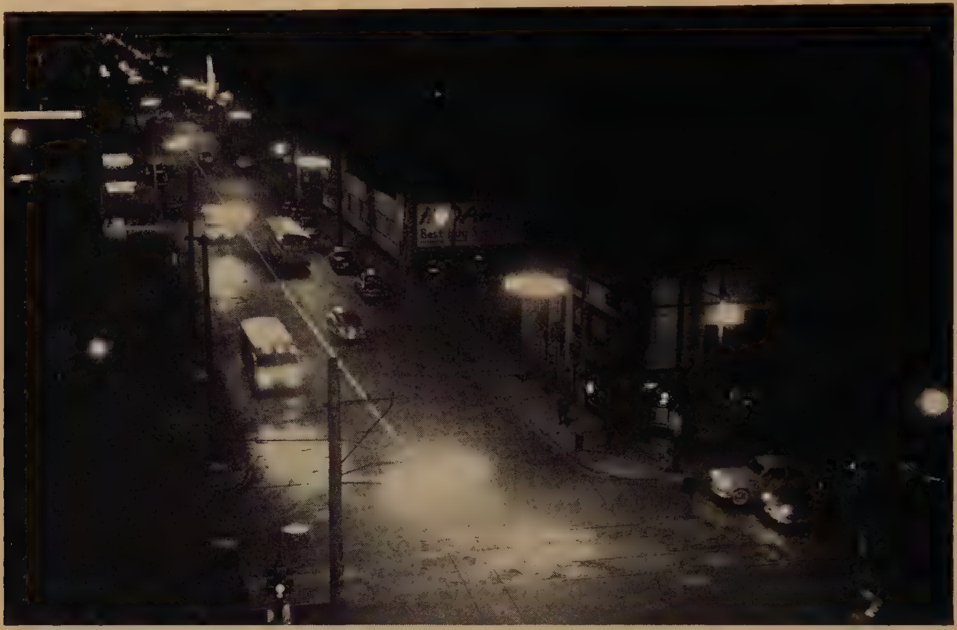


Fig. 3. Fluorescent street lighting in Detroit. Form 200 twin-reflector luminaires

The luminaires along Detroit's Wyoming Avenue (Fig. 4) are spaced 140 ft between intersections and 100 ft at intersections in a staggered arrangement. Mounting height is 25 ft. The resulting average one footcandle of virtually glareless illumination on the pavement has been widely acclaimed for its quality, beauty, and comfort.

Additional installations of fluorescent street lighting will be lighted in the next few months in Schenectady (N. Y.), Portland (Ore.), and Lyndonville (Vt.). Other applications of fluorescent lamps for roadway lighting in this country may be found in the twin Brooklyn Battery Tunnel, where 5776 lamps are used, and for the lighting of a number of railway underpasses. The tunnel lighting has been so successful that several more similar installations are now under way.

Report on Fluorescent Street Lighting

From a very complete report covering the fluorescent street-lighting systems in England, and from observations made at Lynn and Detroit, the following
ments can be made concerning this form of lighting

(1). There is considerably less glare from
form of lighting than from the best engineered
tems using filament and mercury lamps.

(2). Because of the elongated horizontal sou
the wide reflections from fluorescent luminaires
to merge and produce an even pavement brightn
of a high order; this especially aids visibility by
houette when pavements are wet.

(3). For the same average footcandles, the fluor
cent-lighted street is far superior to streets
other forms of lighting in visibility, comfort,
over-all appearance. The British report says, "
chief justification for the use of fluorescent str
lighting in Great Britain is the superior seeing con
tions provided. In our experience it has been possi
to produce better results with three 80-watt fluor
cent than with say 400-watt Mercury or 750-w
Tungsten filament. This is due largely to the m
reduced glare, and wherever high brightness sou
are replaced by fluorescent a reduction in the lu
output of the lanterns should be possible whilst
producing better lighting. It is undesirable howe
to reduce the number of points per mile, due to o
considerations."

(4). On the basis of equal average footcand
the initial equipment cost of a system of fluoresc
luminaires in this country will be about twice
for a modern filament or mercury-lamp system.
cost of installing all three systems will be about
same—the fluorescent being slightly more than
filament and the mercury slightly less. The nu
of luminaires required per mile to produce
average of one footcandle on a 40-ft pavemen
47 Form 200 with fluorescent, 36 Form 109
mercury, and 43 Form 101-AR with 15,000-lu

ment lamps. Energy, lamps, and maintenance l be about equal for fluorescent and mercury tems. For the filament-lamp system, these items uld run about 80 percent greater than for the orescent if current cost is one cent per kilowatt-ur.

5). In spite of the approximate double cost of tial equipment, the total cost per year for a mile of orescent lighting probably will not exceed the cost the same footcandle level of filament lighting by er 20 percent. This differential would disappear ere current costs as much as one and one-half nts per kilowatt-hour.

The British report has the following table which ows a preference for the fluorescent system. It ould be noted that calculations were based on 44 minaires per mile of each type, and current at 1.25 nce per kilowatt-hour.

UMMARY OF ANNUAL COSTS PER MILE (44 LUMINAIRES)
(For the steel column and bracket arm)

Lamp	Fluorescent Three 80-watt Normal	Metal Fil. 750-watt
	£	£
al Repayment	249	138
Replacement	100	96
er Replacement (No starters re-red with U.S. Slimline lamps)	13	—
ric Power 25 pence per K.W. hr.)	272	685
cing	88	88
TOTAL	£722	£1007

(6). The British report has the following to say bout maintenance and operation:

"Despite the greater weight and bulk of the lan-rns no difficulty has been experienced in erection nd reports from users are that there are no special eculiarities or difficulties in operation and mainte-ance and that a normally intelligent man, after a ttle training, is able to locate and rectify any trouble at occurs.

"Reflectors and plastic cover are best cleaned by wiping off with a soft wet cloth, frequently rinsed to prevent scratching of the reflector surface. There is a large surface area to clean, but it is all smooth and polished and less trouble is involved than in cleaning prismatic surfaces or surfaces on to which a sooty deposit has been burned by the action of high-temperature sources.

"The cover has proved reasonably robust, the only breakages being the result of extremely rough handling. There are no signs of roughening of the surface due to cleaning or gritty dust in the atmosphere. No trouble has been experienced due to static discharges forming on the plastic and causing dust to collect. On the contrary the outer surface is self-cleaning under British weather conditions in all but very grimy atmospheres and as only a small amount of dust gets into a lantern, in Rugby for example, cleaning once in six months is ample. The reduction in average footcandles on the road surface due to dirt accumulation during six months has been found to be between 15 and 20 percent of the clean-lantern value. The loss due to 12 weeks' dirt accumulation is not appreciable. In London the original monthly cleaning period was extended to two months and then to three, the estimated loss due to dirt accumulation over the three months' period being only 15 percent.

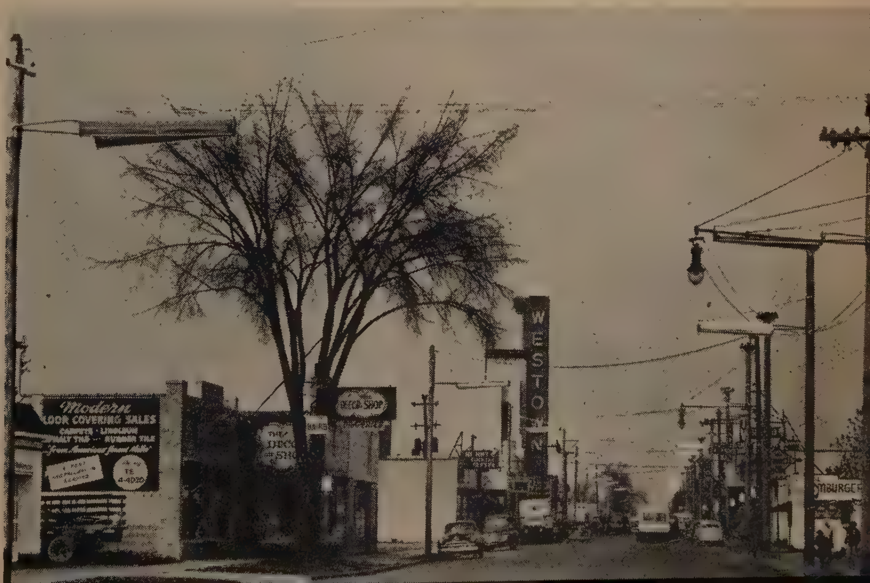
"Depreciation in the lantern itself is negligible.

"The specular anodized-aluminum reflectors have shown no signs of corrosion, even where it would be most expected, in a lantern which had not been cleaned once since it was erected in September 1946. In other cases wiping as recommended had restored the original surface. The excellence of performance is attributed to the comparatively dry atmosphere in-inside the lantern due to the plastic enclosure and to the low working temperature of the source.

"The silicon-aluminum alloy castings have withstood corrosion both in situations near the coast where salt-spray is experienced and in cities where soot and sulphur are present. The roof sheets have been quite free from corrosion.

"Lamp life has proved highly satisfactory."

Fig. 4. A total of 24 luminaires along Detroit's Wyoming Avenue are spaced 140 ft between intersections and 100 ft at intersections



Experience after about a year's operation of the Lynn installation has been almost unbelievably good. No lamps have burned out, fixtures have not been cleaned and do not yet need cleaning. On several sub-zero nights, the lamps have all started readily, and the reduction in light output could not be readily noticed. The correcting of these two troubles evident in early trial installations can be credited to the change to the instant-start Slimline lamp. The eight-foot-long fixtures have successfully weathered several storms—one with the highest wind velocities and the greatest destruction to property ever recorded along the New England coast.

(7). Due to several years of experimentation with both fluorescent lamps, ballasts, and outdoor luminaires, those now available have reached a certain degree of standardization which will probably prevent obsolescence in the foreseeable future. Improvements in lamps will be incorporated into the present highly efficient well-engineered luminaires. Changes in luminaires will be in the interest of cost reductions, and designs for special applications, just as has been the case for both interior and exterior lighting over the years.

Conclusions

From the experiences to date in England and in United States, fluorescent street lighting has definit proved that it has a place in the future lighting of least some of our streets. It should be seriously c sidered for lighting main business streets, tra arteries, bridges, tunnels, and underpasses.

With the need of conserving aluminum for armam purposes, it would be unwise to think in terms of la systems of fluorescent street lighting at the pres time. It would be in order, however, to proceed w perhaps fifty small trial installations of from six t dozen luminaires. These would give municipal a central-station engineers valuable operating expe ence, which would ultimately lead to reduced costs.

We should not forget that fluorescent indoor lighti was thought too expensive when first introduced, b later it led to our present high levels of industrial a commercial lighting. Fluorescent street lighting m well give us the means of providing our streets w much more light than they now have and of a quali which will make the period ahead of "night living" c of real pleasure, comfort, and security.

Crystal-electric Inspection of Industrial Products

A possible new field of crystal-electric engineering was opened by a recent discovery that promises to make possible for the first time the high-speed automatic x-ray inspection of thousands of industrial products. It may also be used to improve the performance of medical diagnostic and therapeutic x-ray apparatus.

The "heart" of the new inspection system is a tiny crystal, known as a semiconductor, which can be grown in size from a fraction of a millimeter to several millimeters in cubic size. When excited with x-radiation, it acts as an amplifier tube, releasing torrents of electrons that can be used to operate various types of mechanisms.

The crystals amplify the energy they receive 1,000,000 times. On an area-for-area basis, they are over 1,000,000 times more sensitive to x-rays than are ionization chambers, which are commonly used to measure x-radiation, and over 1000 times more sensitive than photoelectric cells, such as those used in "electric-eye" applications.

Besides being extremely sensitive, the crystals are stable, and instantly respond to variations in the intensity of x-rays. Because of the 1,000,000-to-1 gain permitted by the crystals, they do the work that hitherto required a much more complex system of vacuum tubes and amplifiers, while at the same time allowing the use of low-intensity x-rays. Pilot laboratory installations of the new system have been built to inspect rubber heels, the product level in canned and packaged products, and the continuity of the powder trains used in blasting fuse.

The crystal-electric method promises to perform at unprecedented speeds, ranging as high as 600 units per minute in canned foods and liquids. Operating as a sort of industrial "slave eye," the crystals may solve many kinds of inspection problems, including: (1) controlling and check the product level in containers; (2) dete ing voids, cracks, cavitation, and variat in material thickness in a wide variety homogeneous materials; (3) checking absence, misplacement, or misalignmen inserts and other internal parts; and e eventually (4) spotting foreign particle foods, metals, and other products.

Glass Insulation Increases Life of Cast-in-Concrete Reactors

A new glass insulation is now being used to increase the life of cast-in-concrete reactors. Capable of withstanding extremely high operating temperatures without deterioration, the new insulation is free of the metallic impurities found in most asbestos tapes and provides more dielectric protection against turn-to-turn short circuits than other types of wound insulation used in reactor manufacture. Moreover, glass insulation is comple unaffected by moisture.

The improved air-core current-limit reactors are also wound with continuo transposed conductors which will prod lower power losses and greater sh circuit strength. Metal housing minim stray current and electrical losses and p vides additional protection against poss damage from external causes.

Checking the new uni cast-in-concrete reacto

EW CONTROL FOR GH-VOLTAGE INDUSTRIAL MOTORS

Bernard J. Dalton

Operating experience with current-limiting fuses and air-break contactors gives highly satisfactory record in handling requirements of applications in the 2300–4160-volt range

By B. J. DALTON

Industrial Engineering Divisions
General Electric Company

ENERAL-PURPOSE high-voltage motor controllers in the 2300–4160-volt range with current- ing power fuses and air-break contactors have ed general acceptance within the last ten years. vidually, the fuses and the contactors represent r advances in the field of industrial high-voltage rol. In combination, they will adequately and re- y control both the normal motor energy under e service conditions as well as the potentially erous energy of large power systems under ab- al short-circuit conditions.

ent-limiting Power Fuses

G. 1 shows a cutaway view of a current-limiting designed specifically for motor controllers to carry igh inrush currents associated with motor starting. er similar current-limiting fuses are available for sformer and feeder protection. The fuse element sists of a number of parallel strands of fine silver s embedded in granular quartz. The continuous- ent rating of the fuse is determined by the wire and the number of silver wires connected in parallel. hown in FIG. 1, each fuse conductor is made up of ps of wires of different diameter welded together the smallest-diameter wire in the center section. eral wire diameters are used so that melting will t in the center section, where the current density eatest, and then extend to the fuse ends. Successive ting of the several wire diameters effectively limits rate of current decay and thus prevents transient very voltage from exceeding established equipment -potential test levels.

hen the fuse blows, vaporizing the silver wire, the er vapor expands throughout the sand-filled tube re it is condensed, leaving only sand in the arc ns, fused into small, solid, nonconducting quartz amers.

true current-limiting fuse is inherently fast in ration because it must introduce its limiting action re the first natural current maximum; otherwise ould not limit the maximum short-circuit current value lower than a system of a specified kva ca- ty could produce if no fuses were present. Non- ent-limiting fuses, on the other hand, would allow maximum current to flow. The crest value of a offset current occurs one half-cycle after the ption of a fault and the fuses will limit the short-circuit current on a maximum rated fault to less than this value. In a symmetrical current wave, this limiting action occurs before one-fourth of a cycle has elapsed.

Fuse Ratings

Fuses of the type shown in FIG. 1 have an interrupting rating of 150,000 kva at 2300 volts and 250,000 kva at 4160 volts, both on a 3-phase, 60-cycle basis. This means that they are suitable for application on power systems which will develop 150,000 kva symmetrical at 2300 volts and 250,000 kva symmetrical at 4160 volts under short-circuit conditions. These interrupting ratings correspond with interrupting ratings of conventional high-interrupting-capacity power circuit breakers and have been established so that fuses can be applied from an interrupting standpoint in the same way that power circuit breakers are applied.

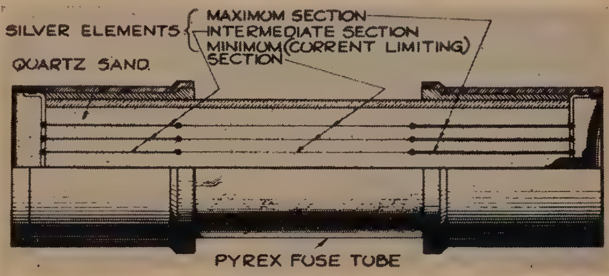


Fig. 1. Cutaway view of a current-limiting power fuse, of 2500 to 5000-volt design

Since the fuses function within the first half-cycle on rated fault current, when the transient is greatest, they may be called upon to interrupt, at least potentially, higher current than would a conventional power circuit breaker which opens when the transient has largely decayed. Such a condition will occur if the short circuit starts at a normal voltage zero. The total current in this case consists of the steady-state fault current and the d-c transient current. The total current is usually called the offset or asymmetrical current and the rms value has been established by AIEE as 1.6 times the steady-state or symmetrical rms fault current. The asymmetrical current attenuates rapidly and reaches a steady-state value in a few cycles.

The fuses have a maximum current rating of 60,000 amp rms asymmetrical. The fuses will, however, actually limit short-circuit current to less than the crest value

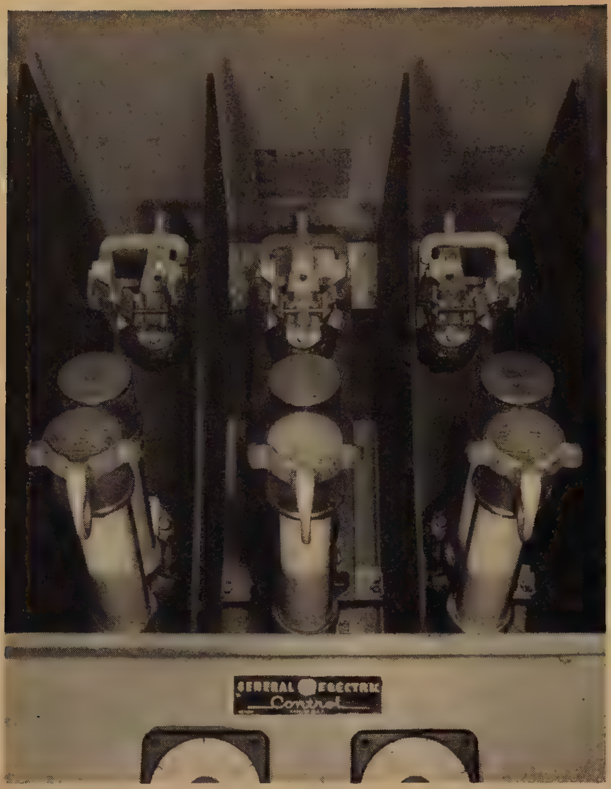
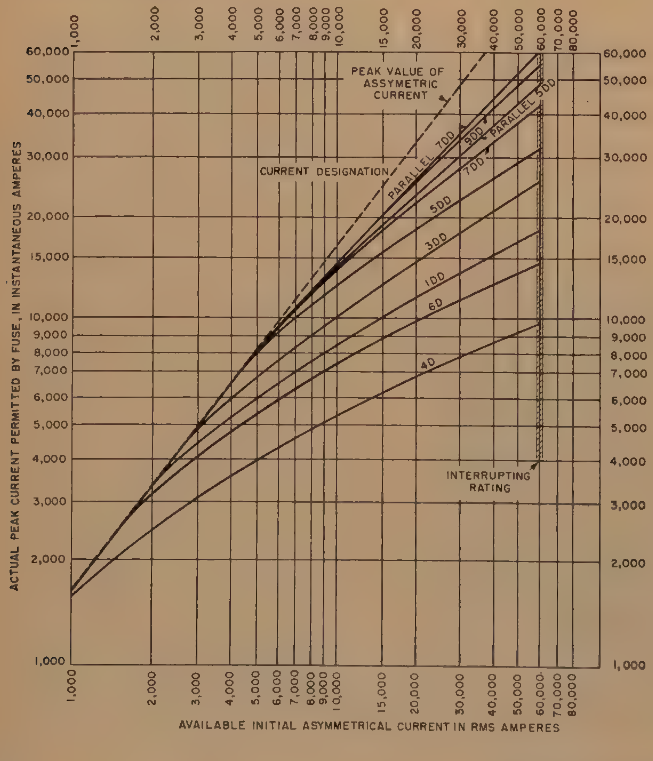


Fig. 2. Installation of double-barrel fuses in a controller for full-voltage starting of a synchronous motor

of a 60,000-amp rms asymmetrical fault. The maximum current rating is used to establish the maximum capacity of the system to which fuses may be applied.

Different length fuses are used for the two voltage ratings: 2500-volt-class fuses can be applied on systems from 1750 volts to 2500 volts; and 5000-volt-class fuses can be applied on systems from 3500 volts to 5000 volts. The fast interruption of current by cur limiting fuses produces transient voltages which permissible when the proper fuses are used. If volt fuses were used on a 2500-volt system, how the transient voltage might be sufficient to punc insulation. When fuses are applied in the rang voltage mentioned, either the maximum kva r or the maximum current rating may establish application limit. With 2500-volt-class fuses, for ample, the kva rating will limit the application a 2300 volts and the maximum current rating will the application below 2300 volts.

Fig. 3. Performance curves for Type EJ-2 current-limiting fuses under short-circuit conditions



Fuse Selection

Selection of the proper fuse size for carrying no current is determined both by motor full-load cur and by motor locked-rotor current. Therefore, no load current rating is assigned. The fuses are, howe given a size number. Single-barrel fuses are used motor ratings up to about 150 hp at 2300 volts. Dou barrel fuses are used for ratings between about 20 and 800 hp at 2300 volts. These fuses consist of independent fuse units with a common ferrule as bly to make a single fuse unit. Double-barrel fuses shown installed in Fig. 2. Parallel double-barrel f are used for ratings from about 800 hp to 1250 h 2300 volts. Fig. 3 shows that current-limiting f become less current limiting as the ratings incre This indicates a natural limit to the maximum that can be built with presently known methods materials. All ratings given in these performa curves apply to induction or 0.8-pf synchronous mo Somewhat larger 1.0-pf synchronous motor ratings apply for each fuse arrangement with a maximu 1500 hp.

The same full-load current sizes are availabl both voltage ratings except that the largest fuses not available for 4160 volts. The maximum horsep rating for 4160-volt parallel fuses is 2250 hp for in tion and 0.8-pf synchronous motors and 2500 hp 1.0-pf synchronous motors.

Air-break Contactors

High-voltage air-break contactors were origi developed for mine hoists where the mainten problems of early oil contactors and the possibilit fire militated against their use. Literally hundred open-type high-voltage air-break contactors been used on mine hoists during the last forty y and have given an outstanding record of perform on duty cycles where the contactors operate u twice per minute on a two-shift basis. Some of t contactors have accumulated millions of operat with only minor maintenance. Fig. 4 shows an inst tion of an early type air-break contactor on a mine h

Continued developments in the science of arc i ruption and other phases of contactor design*

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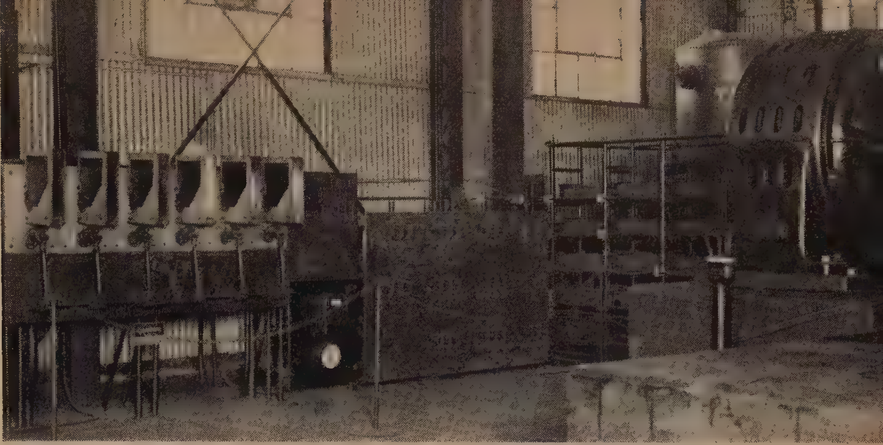
*Some basic considerations and tests were presented in the article Performance of Contactors as Circuit Interrupting Devices," by B. W. and O. R. Schurig, General Electric Review, vol. 39, February, 1 78.—Editor.



Early-type air-break contactor installation on a
oist with 500-hp 450-rpm 2200-volt induction motor.
he contactor operation

ed in improved designs and materially smaller ctor sizes, together with other advantages. This esulted in extensive use of air-break contactors neral-purpose as well as special-purpose metal- sed high-voltage controllers within the last ten

s. 5 and 6 shows the front and back views respec- of a new narrow-type air-break contactor. FIG. ws the contactor with the arc chutes removed. reak contactors of this type offer two distinct ntages over oil-immersed contactors: (1) main- ce is almost eliminated by the extremely long ting life; (2) air contactors do not constitute a azard.

oil-immersed contactors are used in applications they are operated frequently, they must receive ar and frequent oil changes and contact-tip cements. Such maintenance is inconvenient as as expensive and often disagreeable to the extent maintenance is neglected. Air-break contactors, e other hand, require no oil changing and have ct life in the neighborhood of 20 to 50 times the ct life of oil-immersed contactors. Contact life

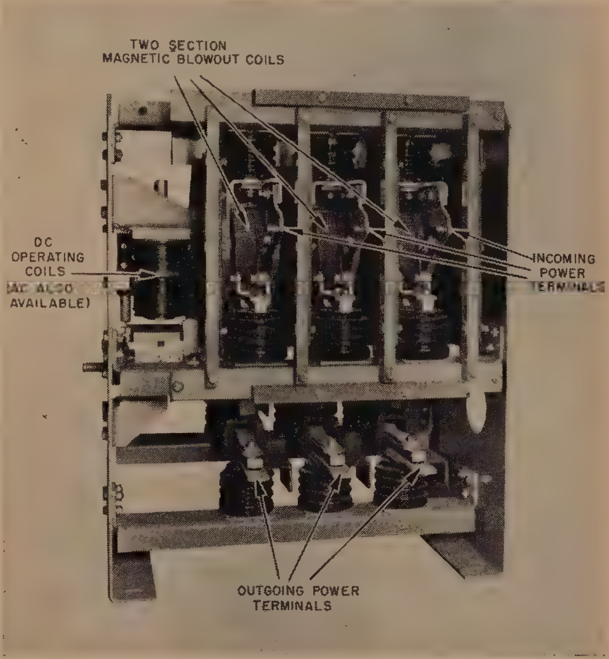


Fig. 6. Back view of narrow-form 5000-volt class air-break contactor

5. Front view of narrow-form 5000-volt class air-break contactor

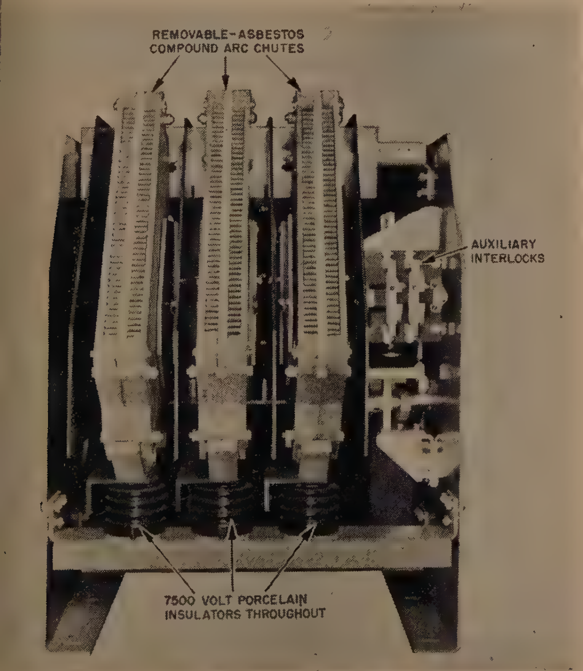
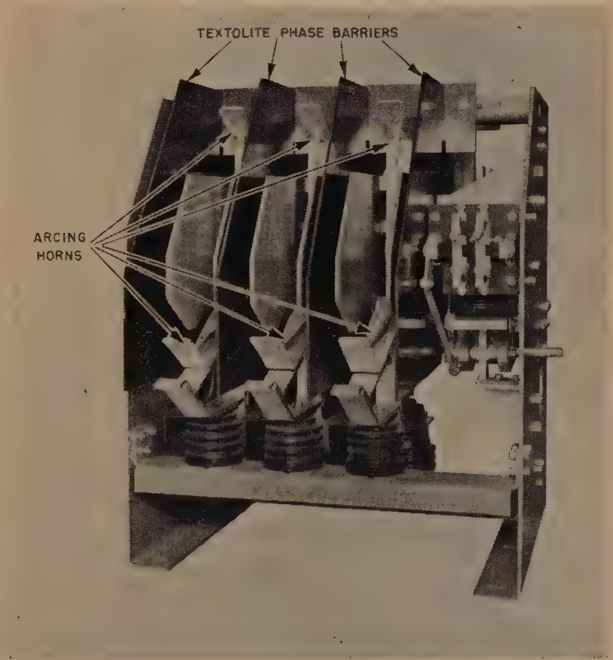


Fig. 7. Front view of 5000-volt class contactor with arc-chutes removed, showing arcing horns and Textolite* phase-barriers

*Reg. trade-mark of G.E. Co.



of 100,000 operations under normal full-voltage motor-starting service is not unusual. In fact, contact life on mine-hoist controllers (which, of course, is not nearly so severe as comparable full-voltage starting, because of the low starting currents of wound-rotor motors) has been as high as several million operations.

TABLE I:

HIGH-VOLTAGE AIR-BREAK CONTACTOR RATINGS

Continuous Ampere Rating (8-hour)	Interrupting Capacity 3-phase Symmetrical kva		Maximum* Momentary Current (noninterrupting) RMS Asymmetrical amp	Maximum Horsepower			
				2220–2300 volts Induction or		4000–4600 volts Induction or	
	2500 volts	5000 volts		0.8-pf Syn	1.0-pf Syn	0.8-pf Syn	1.0-pf Sy
50	12,500	25,000	6000	150	200	300	400
100	12,500	25,000	6000	350	450	600	800
200	25,000	25,000	32,000	700	900	1250	1500
400	25,000	35,000	32,000	1500	1750	2500	3000

* When used with current-limiting fuses, contactors will carry momentary current let-through of fuses.

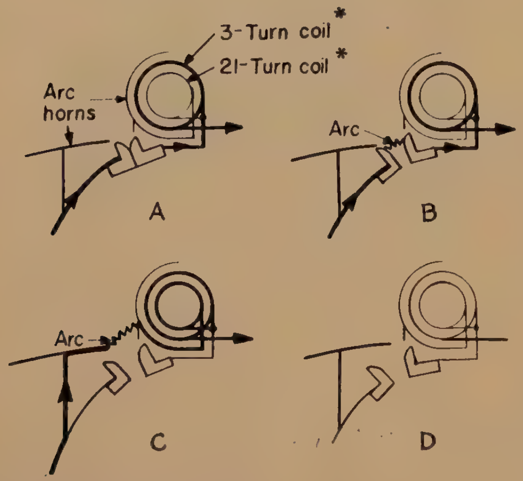


Fig. 8. Sequence of arc interruption in typical high-voltage air-break contactor: (A) normal operating conditions with contacts closed. Current flows through three-turn blowout coil; (B) contacts begin to open; three-turn coil produces flux to force arc upward. (C) Arc transfers from contacts to arcing horns. Current transfer to upper arcing horn introduces 21-turn blowout coil in addition to three-turn coil. (D) Arc extinguished rapidly by increased magnetic flux. (*Number of coil turns shown is illustrative only as typical values for a particular rating.)

The long contact life of air-break contactors is a result of two factors:

(1). The arc is free to expand and is not confined as in the oil-immersed contactor by the surrounding oil. In an oil contactor, burning is concentrated on a small area, while in the air-break contactor, the larger area of the arc results in less tip burning.

(2). In the air-break contactor, the arc is removed quickly from the current-carrying tips, thus minimizing contact burning. This is accomplished by the blowout coils forcing the arc onto the arcing horns as shown in the sequence A, B, C, D in Fig. 8.

The possibility of fire resulting from oil-imme contactors is slight under normal operating condi when contactors are properly maintained. Neverthe rapid and successive jogging or short-circuit condi may cause vaporization of oil and internal pres sufficient to deform or rupture the oil tank and, ir worst case, to start an oil fire. Since oil is elimin entirely with air-break contactors, any possibilit fire due to oil is also entirely eliminated.

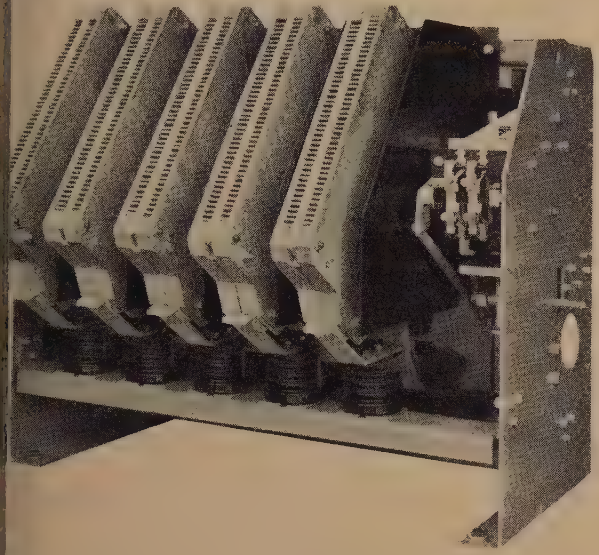
Air-break contactors are available in several mec ical arrangements. The three-pole contactor form illustrated in Figs. 5, 6, and 7. A five-pole conta as shown in Fig. 9 is also available for reduced vol starters or for multi-speed motors. Fig. 10 sho special contactor form for rubber-mill service. consists of a 3-pole line contactor and a 3-pole norn closed dynamic braking contactor in a single com assembly. The normally closed poles are not usec current interruption and, therefore, have no blo coils or arc chutes. All contactors are arranged so mechanical interlocks can be added. A-c or d-c ating coils can be furnished in the three-pole form. coils only are available in the other forms becau the greater magnetic pull required.

Table I shows the ratings for the new air-break tactors. These ratings apply to the contactors and not necessarily to the entire controller. Se ampere ratings are used to provide blowout coils will furnish optimum blowout flux for all motor ra and over a wide range of motor load. The kva i rupting rating is the rating of the contactor itself used with no other circuit interrupting means lower voltages than those listed for the interru rating, the kva interrupting rating is in some decreased somewhat. The maximum momentary rent rating is of value when the contactors are ba up by power circuit breakers which interrupt currents.

The new air-break contactor has an additiona vantage for the rubber industry where control ating time must be very short to reduce mill-roll t

Fig. 10. Combination three-pole line contactor and dynamic-braking contactor for rubber-mill service

9. Five-pole air-break contactor for multispeed motors or reduced ge starters



ng emergency stopping. Operating tests conducted a sample combination line and dynamic-braking actor before and after many thousands of mechan- operations, and over a wide range of operating-coil age, indicate that the dynamic-braking circuit be established in the order of 0.075 sec after the ent in the line and dynamic-braking coils is in- upted. This is equivalent to only 0.125 percent travel; and, for 100-fpm mill surface speed, this is valent to approximately 1.5 in. of travel.

rdination of Circuit Elements

he entire power circuit in a controller must be rdinated to provide reliable operation under all nal conditions and to provide adequate protection nst all overload conditions within the rating of controller. And this must be accomplished with a imum of normal maintenance and without un- ssary blowing of fuses, tripping of overload relays, erious equipment damage.

eavy-duty air-break contactors provide the features ssary to give reliable operation under the most re operating conditions, including frequent jogging. current-limiting fuses must be, and are, so designed applied that they will not blow or even deteriorate r such normal conditions. In the event of too- uent jogging or overload conditions that would e motor overheating and resultant damage to the lings, the overload relays should operate to remove or power, although the overload relays should not the motor off the line unnecessarily. When fault currents appreciably higher than locked-rotor current flow, however, the fuses must operate to clear the feeder. All current-carrying parts, including the bus and cable, the contactor, and the current transformers must have sufficient mechanical strength to withstand the extremely high electromagnetic forces associated with high fault currents.

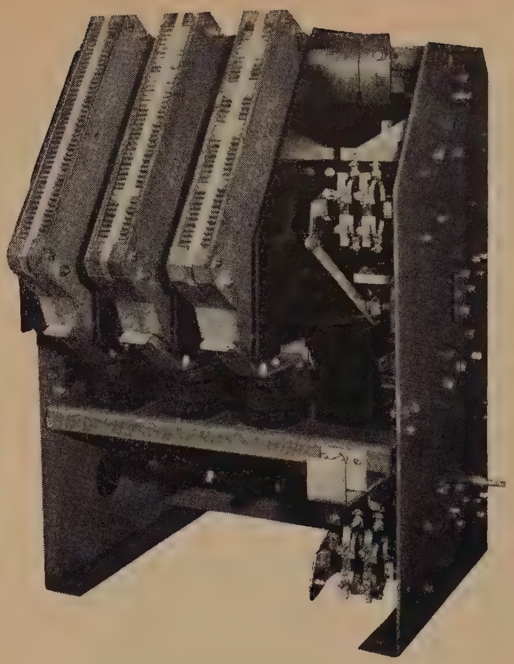
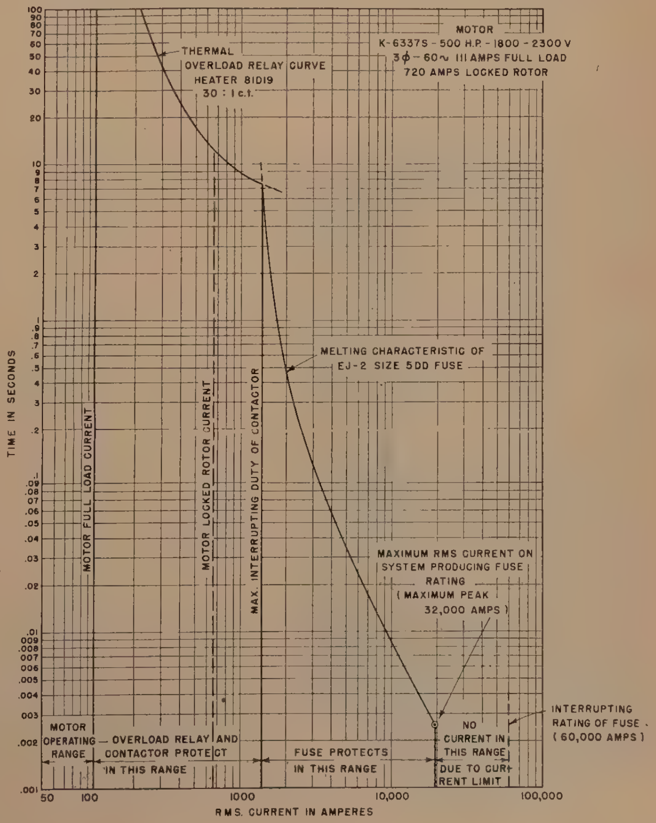


FIG. 11 is a typical co-ordination curve showing how the tripping characteristic of the thermal overload

Fig. 11. Curve showing co-ordination of tripping characteristic of thermal overload heaters and melting characteristics of current-limiting fuse for a typical equipment



relays and the melting characteristic of the fuses are co-ordinated so that the overload relay and contactor protect the motor below about 10 to 15 or more times motor full-load current and so that the fuses protect the entire system above about 10 to 15 or more times full-load current. In all cases, the contactor is capable of interrupting all currents below that required to melt the fuses.

Fig. 3 showed the current-limiting action of several sizes of Type EJ-2 current-limiting fuses. It is apparent from these curves that the current "let through" increases with the size rating of the fuses. This means that under short-circuit conditions the electromagnetic forces on the contactor and other components of the power circuit increase in the larger ratings. And since such forces increase in proportion to the square of the current, the momentary forces involved in the parallel size 7DD fuses are about 40 times as great as in the size 4D fuses. Extensive short-circuit tests have been made on combinations of current-limiting fuses and contactors and on complete controllers to be sure that the contactors and the other power circuit elements are capable of handling the forces involved in all cases.

The complete controller rating must be based on the composite rating of all the pertinent devices. The maximum rating of complete controllers with Type EJ-2 current-limiting fuses and with the air-break contactors described has been established as shown in Table II.

There are sometimes cases where users wish to apply current-limiting fuses to existing controllers. Such an application involves a study of all current-carrying parts to determine whether each component will withstand the short-circuit forces involved. Most manufacturers of high-voltage control equipment are in a position to make such studies and recommendations concerning current-limiting fuses.

Control Features

Fig. 12 shows a general-purpose nonreversing
troller for a synchronous motor. Fig. 13 sho
reversing dynamic braking controller for a synchro
motor for a rubber mill. The rubber-mill starte
cludes a high-voltage a-c bus structure as well a
control power bus and potential metering bu
facilitate the line-up of the starter with other
With cover plates for both sides of the enclosure,
starter can be used as an individual unit or in
line-up arrangement. Controllers of this type
available with or without a bus assembly.

Fig. 14 shows an inside front view of a reve
dynamic-braking synchronous-motor controller. Se
important features of this controller are common
general-purpose and special-purpose controller
this type:

(1). The fuse compartment and the low-vol
compartment are independent sheet-metal iso
compartments with separate doors.

(2). Ambient temperature-compensated induc
type thermal overload relays are used to provid
optimum degree of motor overcurrent protectio

(3). Undervoltage protection can be re
changed from instantaneous dropout to time-d
dropout to suit the particular operating requirem
In a plant with a few essential unattended mach
time-delay undervoltage may be highly desir
but in a plant with a large majority of its p
demand in large high-voltage motors, the us
time-delay undervoltage may result in shutdow
the entire plant system if all motors restart
matically after a power dip.

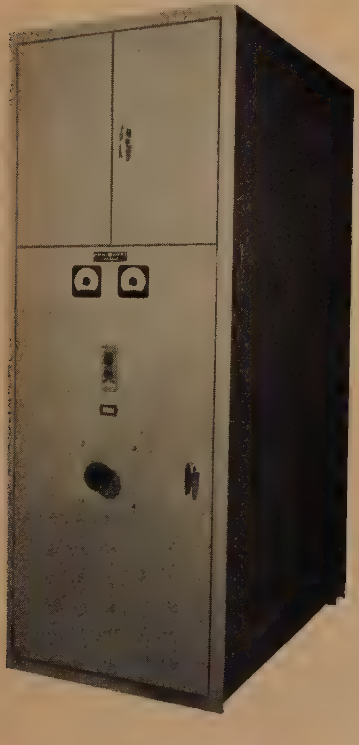


Fig. 12. General-purpose nonreversing synchronous-motor controller

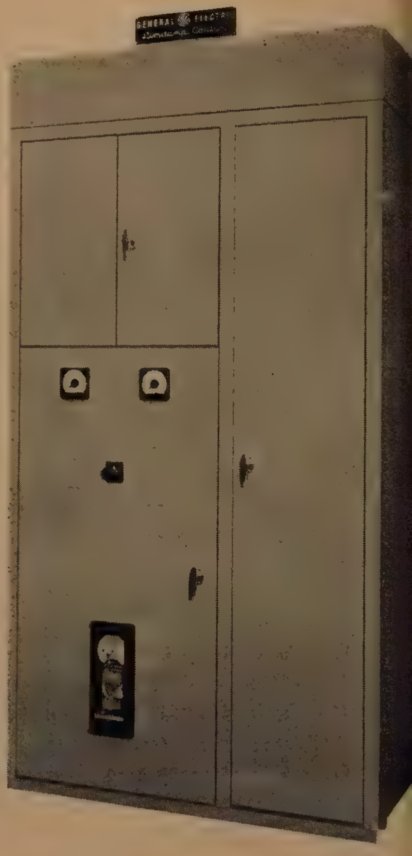


Fig. 13. Reversing dynamic-braking synchronous-motor control for rubber mill. With overhead power bus structure

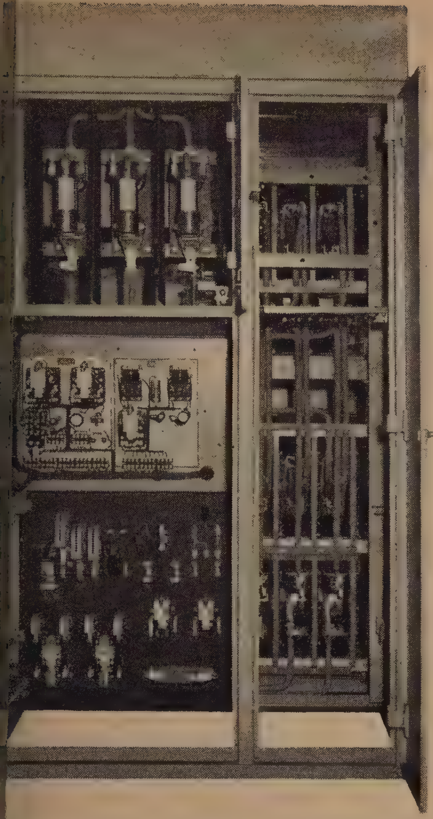


Fig. 14. Reversing dynamic braking synchronous-motor control with front doors open

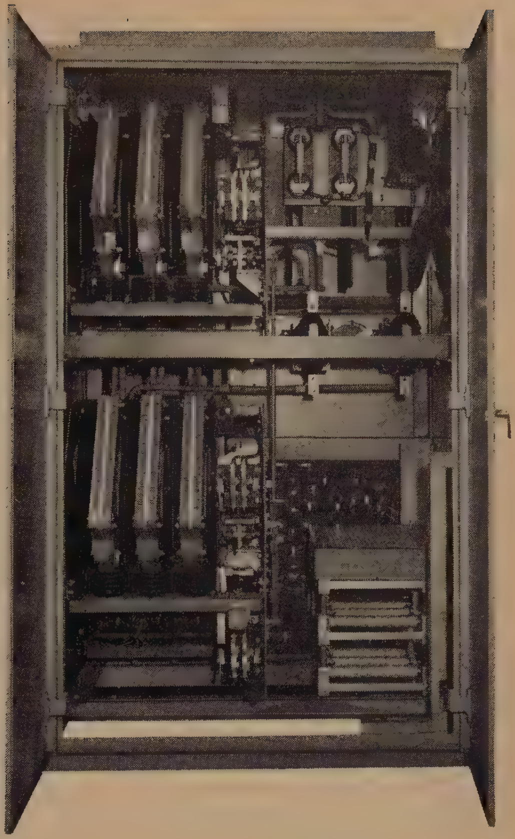


Fig. 15. Back view of the starter shown in Fig. 14

(4). In synchronous-motor controllers the control arranged so that it can be readily changed from itdown on pull-out to resynchronizing after pull-t. The use of one connection or the other is de-ıdent on the type of load being driven and whether load can be resynchronized after pull-out.

e back view of the starter in Fig. 14 is shown in 15. Current-limiting fuses as shown are con-d in the control transformer primary and are used high-voltage control equipments.

e development of the new narrow-form air-break ıctor has resulted in a substantial reduction in the space required by controllers with these con-rs, as compared with the older forms. Table III over-all dimensions for several starter types. cal predecessor starters had widths of from 3 ft 6 in. for a general-purpose 2300-volt starter to 15 ft wide for a 4160-volt, two-speed reversing controller. The floor area required for such controllers has been reduced 10 to 50 percent or more, depending on the type and voltage rating of the specific starters.

Operating experience with control of this type under all conditions, including short-circuit, has been extremely gratifying both to users and to manufacturers alike. Testimony from users certainly justifies the prediction that control with current-limiting fuses and air-break contactors will be the control of tomorrow.

E II: RATINGS OF COMPLETE HIGH-VOLTAGE CONTROLLERS WITH TYPE EJ-2 CURRENT-LIMITING FUSES

		Maximum HP Rating	
olts(a)	Interrupting KVA(b)	Induction or 0.8-pf Synchronous	1.0-pf Synchronous
300	150,000	1250	1500
160(c)	250,000	2250	2500

50 or 60 cycles

On a 3-phase symmetrical basis

Suitable for systems with sustained levels up to 5000 volts

TABLE III: OVER-ALL DIMENSIONS OF 2300- AND 4160-VOLT ENCLOSED CONTROLLERS WITH AIR-BREAK CONTACTORS AND CURRENT-LIMITING FUSES

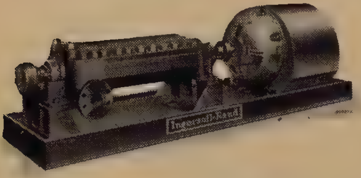
(Dimensions apply to synchronous- and induction-motor starters)

	Width
Full-voltage, nonreversing	2 ft 10¼ in.
Reduced-voltage reactor starter nonreversing	4 ft 6¼ in.
Full-voltage reversing	4 ft 6¼ in.
Full-voltage reversing with dynamic braking	4 ft 6¼ in.
Full-voltage two-speed two-winding nonreversing	4 ft 6¼ in.
Full-voltage two-speed two-winding reversing	5 ft 8½ in.
Full-voltage two-speed one-winding nonreversing	5 ft 8½ in.
Full-voltage two-speed one-winding reversing	7 ft 4 in.

All controls are 5 ft ¼ in. deep and 8 ft 10⅛ in. high including 10⅛ in. bus compartment, 2-in. floor channel and 4-in. lifting angle.

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Centrifugal Pumps



A line of multistage centrifugal pumps, Class HMTA, for high-pressure applications of 1200 psi and capacities to 1600 gpm. Built in 3-, 4-, 5-, and 6-in. sizes with 3 to 9 stages, these pumps are efficient, easy to maintain, and dependable. Applications cover a wide range of boiler-feed, pipe-line pumping, and refinery, as well as other general high-pressure industrial services. Features of the new design are its cylindrical-bore horizontally split casing and compact unit-type rotor assembly, composed of the shaft, impellers, and channel rings. This entire assembly is quickly and easily removed from and installed in the smooth-bore casing, since there are no mating-ring fits or delicate alignment problems.—*Ingersoll-Rand Co., Phillipsburg, New Jersey.*

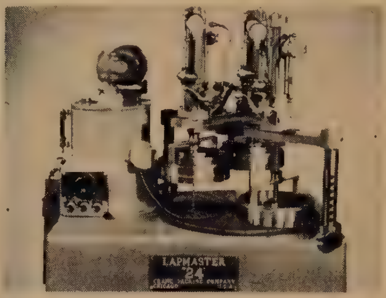
Ball Bearings

A ball bearing, series RF, sealed without any mechanical contact between its stationary and rotating members combines the advantages of a sealed bearing with the freedom of rotation of an open bearing. The capillary chamber is formed by the cylindrical extruded section of the inner cover and the tapered section of the inner race. At this point a permanent capillary film of oil seals the bearing. Made of high-quality bearing steel with its accepted advantages of hardness and finish, the combination of the capillary seal and the plating produces a corrosion-resistant bearing. Bore sizes are from 3 mm to 8 mm with corresponding outside diameters of 10 mm to 22 mm.—*Landis & Gyr, Inc., 104 Fifth Ave., New York 11, N. Y.*

Metering Pump

A metering pump for hot waxes and cements designed for a wide variety of applications. It is currently used for filling capacitor cases, transformers, weatherproof sockets, switch parts, brush handles, selenium rectifier ends, etc. The device is a variable-discharge spur-gear pump equipped with a single-revolution clutch. A bronze 1½-gal tank is mounted over the metering section. There are many nozzles to meet different filling requirements. An important fact is that the gear pump ejects hot waxes and cements with an accuracy of ±3 percent, and at a high speed of ⅔ sec per ejection.—*Edward E. Robinson, Inc., 95 Park Ave., Nutley 10, New Jersey.*

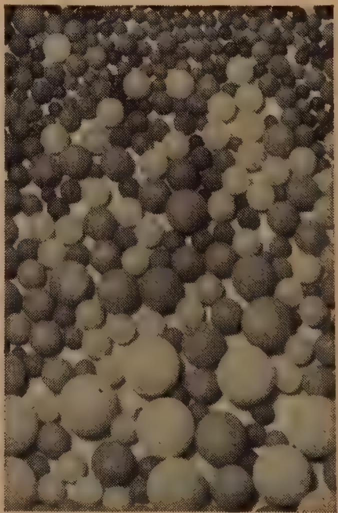
Lapping Attachments



Two special standard attachments—roller bar and pneumatic lifts—enable users of Lapmaster lapping machines to speed production and simplify handling of parts. The roller bar was designed to facilitate loading and unloading of tall or large parts. It makes use of conditioning ring-holding brackets mounted outside the circumference of the lap plate. Slots allow adjustment of these brackets, and complete accessibility of the lap plate is afforded. When large numbers of small parts must be lapped, the pneumatic lift facilitates loading and removal of parts and workholders. Each conditioning ring and pressure plate unit is individually raised by a lift. When the lapping cycle stops, each lift is quickly raised by pneumatic pressure, lapped parts removed, and preloaded workholders placed in position, all within a minimum of time. —*Crane Packing Co., Dept. D-9, 1800 Cuyler Avenue, Chicago 13, Illinois.*

Plastic Balls

Precision seamless nylon plastic balls, FM No. 10001, mass-produced to close tolerances for use in valves, valve components, specialized friction bearings, detents, mechanical checks, and numerous other commercial and industrial applications.



These balls, in sizes from ⅛ in. to ¾ in., and with tolerances to ±0.001 provide toughness at low temperatures, are abrasion-resistant, offer stability at high temperatures, lightness in weight, and chemical resistance.—*Ace Plastic Co., 91-30 Van Wyck Blvd., Jamaica 1, New York.*

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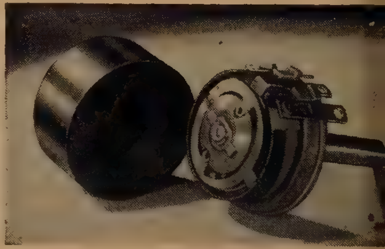
thickness of aluminum foil anodized
dyed to government specifications,
backed with a high-tensile bonding mat
They can be applied quickly to any
cohesive surface on metals, porcelain,
lite, polystyrene, glass, wood, paints
enamels. Permanent clarity and legibili
the letters and characters are assured
processing which makes them a part
aluminum foil itself. The plates are
able in a variety of colors.—*C & H*
Co., Metal-Cal Div., Seattle, Wash.

Potentiometer

A special precision-built potentio
designed to meet exceptionally rigid
chanical and electrical specifications.
tapered winding is held to a toleran
±1½ percent linearity as measured
test points. Mechanical tolerances are
as close as ±0.00025 in. The unit ope



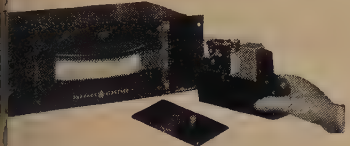
dependably over extreme ranges of te
ature; humidity and altitude or barom
pressure; and under severe vibra
Treated to meet fungus and corrosive
ditions, the body of this control is
in yellow or low-loss Bakelite. Po
low-loss conductivity is assured by
silver contact carried by the ring-sh
slider which rides the winding, as w
the contact rail. A slip-on plastic cap
tects the control mechanism.—*Cla*
Manufacturing Co., Inc., Dover,
Hampshire.

Radiation Detector

An atomic radiation detector or mo
that permits direct-radiation readings
glance. Measurements are read from
monitor simply by noting the position
pointer as it moves across a graded
The pointer's speed across the scale
proportion to the strength of radiation
the distance it moves in a given time
cates the amount of radiation to whic
instrument has been exposed. Its ext
sensitivity, coupled with a continu
visible indication, will give warning
radiation hazard while there is still ti
avoid excessive exposure. The instru
weighs less than a pound, is about the
a quart oil can, is equipped with a
contained power source, and has n
tubes nor batteries.—*General Electric*
Schenectady 5, N. Y.

Pyrometer Equipment

meter equipment offering accurate ature indication; close temperature of industrial processes; and protec- furnaces, ovens, and kilns. The line of flush- or surface-mounted indi- controllers, and protectors. Designed



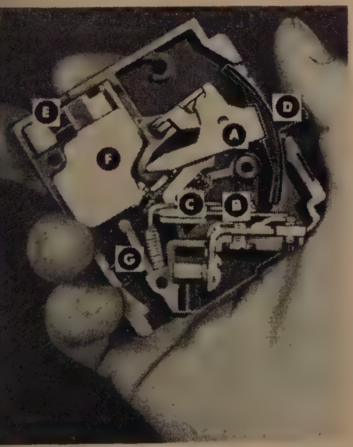
ustrial applications, the instrument calibrated accuracy within ¾ of 1 of full scale. A legible 7-in. scale es any change in temperature equiv- 1/10 of 1 percent of full scale. Im- e control action follows, the exactness h is practically uneffected by normal s in humidity, ambient temperature, age.—*General Electric Co., Apparatus Schenectady 5, N. Y.*

Male Thread Bushing

ale thread insulating bushing to serve lectrical field. An outstanding feature bushing is the ribbed outer surface itate installation by providing a sure Ribs can also be used as a driving for tapping bushing with a screw- Other features include clean, deep s for faster, easier spin-on, and , rounded edges for protecting wire ion during pulling and while in . The bushing can be used in con- n with either a lock nut or O.Z. insulating bushing.—*O.Z. Electrical acturing Co., 262 Bond St., Brooklyn,*

Plug-in Circuit Breaker

ug-in type TQL circuit breaker for 50 amp services, having quick-make break operation and thermal-mag- protection. The breaker utilizes a main operating spring which takes ion out of the hands of the operator, he handle has been moved. Contacts ened and closed with a fast, clean avoiding excessive burning or arcing contacts due to improper operation.



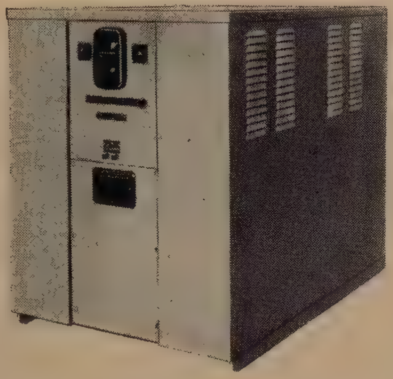
al action of the bi-metal trip element ds to an overload condition, although ss temporary overloads will be passed t opening the circuit, and magnetic instantly opens the breaker if a circuit occurs.—*Trumbull Electric acturing Co., Plainville, Conn.*

Noncutting Metal

A noncutting metal, called Hevimet, that is even heavier than cemented carbide and with 50 percent greater density than lead. Important uses of this special metal—besides its ability to resist the penetration of radioactive rays—are for balance weights on crankshafts, gyroscopes, variable-pitch propellers, centrifugal clutches, and other similar moving parts. For static and dynamic balancing of such parts, as well as for balancing of aircraft control surfaces, etc., it has the advantage of maximum weight with minimum size. Because of its high density, it can be used for gamma-ray screens in radiotherapy and other similar applications.—*Carboloy Co., Inc., Detroit 32, Michigan.*

Power Pack

A midget inductrol power pack load-center unit substation designed for low-voltage, regulated a-c lighting, and power service in factories and laboratories. Incorporated in one steel housing is an air circuit breaker, a dry-type transformer, and an air-cooled induction regulator. In either single- or three-phase ratings, the pack has a capacity ranging from 15- to 100-kva, with incoming circuit rated 480 or 600 volts, 60 cycles, and a regulated output at 120/240 or 208Y/120 volts. With these units, power can be brought to the load area at relatively high voltage with substantial savings in cable. The pack can be used to regulate the power supplied to resistance heating and infrared heating equipment, electronic apparatus, precision instruments, and control circuits, and commercial electric cooking equipment.—*General Electric Company, Unit Equipment Division, Schenectady 5, New York.*



Lacquer Finishes

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188	338	700	1250	1800
200	350	750	1300	1850
213	363	800	1350	1900
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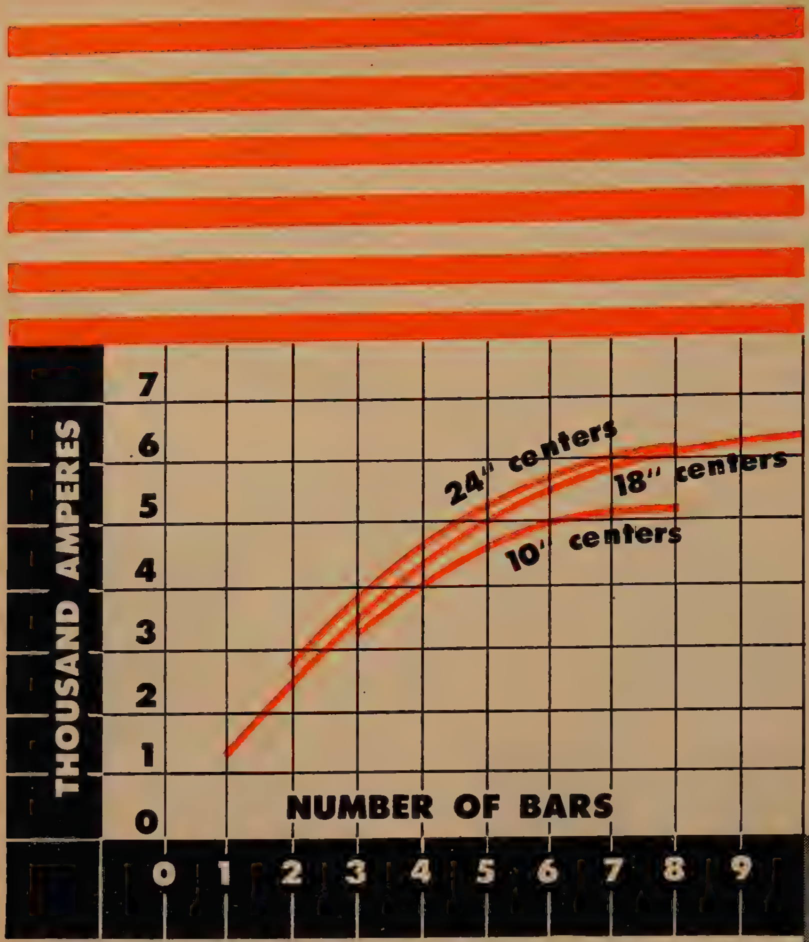

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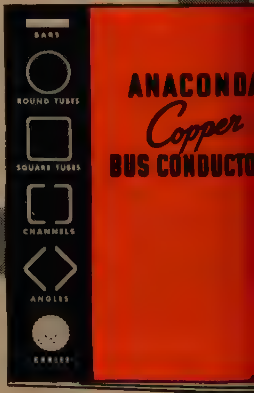

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Aluminized Steel—Steel with a special coating of aluminum is the subject of a booklet describing this type of a surface. Attention is given to its heat and corrosion resistance and heat reflectivity. High-quality illustrations show a variety of applications. Suggested methods of welding, brazing, and finishing are included. Twenty-four pages.—*Armco Steel Corp., Middletown, Ohio.*

Ball Bearings—A bearing booklet giving specifications on more than 70 different types and sizes of miniature ball bearings. Covers design factors, typical applications, and design variations. Twelve pages. Catalog 51b.—*Miniature Precision Bearings, Keene, New Hampshire.*

Capacitors—Engineering bulletins describing miniature ceramic-disk Tiny Mike series capacitors for by-pass and coupling in five basic types in diameters of ¼ in.; 19/32 in.; ¾ in.; and 19/32 in. and ¾ in., both dual-capacity units. One page each. Bulletin Nos. 2–610; 2–611; 2–612; and 2–613, respectively. Also folder describing the new by-pass and feed-through vehicular capacitors, series MC, for the suppression of radio-frequency interference. Four pages. Bulletin NB-140.—*Cornell-Dubilier Electric Corp., South Plainfield, New Jersey.*

Centralized Control—Presents the what and why of Multitrol control centers with an explanation as to what each type of unit contains. Four pages. Bulletin 4410.—*Ward Leonard Electric Co., Mount Vernon, New York.*

Diamond Tools—Describes Steelset sintered-steel bonded diamond tools used for drilling holes, biscuit cutting, and internal grinding of glass, porcelain, ceramics, quartz, etc. Twenty-four pages. Catalog DT337.—*Fish-Schurman, 230 East 45th St., New York 17, N. Y.*

Fluid-flow Rate Testing—A technical report of comprehensive data on the newest technical developments on fluid-flow rate testing for the aviation industry in particular. Engineering principles, detailed flow curves, and tabulation charts are included. Describes calibration techniques and illustrates modern precision-accuracy calibration panels. Twenty pages. Technical Bulletin A-9C-4.—*Fischer & Porter Co., 3780 County Line Rd., Hatboro, Pa.*

Insulating Fire Brick—An illustrated descriptive folder highlighting the use of JM-3000 insulating fire bricks and briefly covering economic advantages, industrial applications, and refractory properties. Four pages.—*Johns-Manville, 22 East 40th St., New York 16, N. Y.*

Laminated Plastics—An attractively designed 1951 catalog which is divided into four main sections covering vulcanized fibre, phenol fibre and special laminates, design and machining hints, and engineering and research facilities. Charts and tables on engineering data are included. Sixty-two pages.—*Taylor Fibre Co., Norristown, Pa.*

Metal Stampings—Presents by word
picture a tour of a precision stamping
wherein an intricate stamping proble
handled completely—from creating or r
fying the design, to engineering and m
facturing the tools and dies, through to
ducing it in volume on automatic pr
Make requests on company letter
Sixteen pages. Titled "3-Way Faciliti
Precision Stampings."—*John Volkert*
Stampings, Inc., 222–34 96th Ave.,
Village 8, New York.

Precision Equipment—A line of pre
equipment for small-parts manufact
and maintenance is described. Include
small-parts cleaning machines, cleaning
rinsing solutions, flexible-shaft equip
polishing motors, crystal cement, etc.
pages.—*L & R Manufacturing Co., 57*
St., Arlington, New Jersey.

Radio Interference Locator—A
prehensive explanation of the operati
Model 302 radio interference locat
sturdy portable instrument designe
meet the needs of electric utilities and o
interested in man-made radio noise loc
and reduction. Four pages. Form PF
—*Sprague Electric Co., North Adams,*

Speed Control—A booklet describin
opportunities afforded by adjustable-
drive, with threefold purpose: to pres
concise summary of specific benefit
dustry can expect from properly ap
adjustable speed; to provide a check
considerations in selection; and to g
clear picture of the range of applicatio
performance features of various pa
drives. Twenty-four pages. GEA-53
Apparatus Department, General El
Company, Schenectady 5, New York.

Tachometers—The Frahm resonant
tachometers for hand use or perma
mounting are described and illustr
Proper selection, ranges, application,
ordering information are among the su
covered. Sixteen pages. Bulletin 31-
James G. Biddle Co., 1316 Arch St.,
delphia 7, Pa.

Vacuum Coating Units—A data
describing in detail the construction,
bilities, and performance of vacuum co
units employed for such uses as shad
electron microscope specimens, manufa
ing telephone capacitors, and reclai
waste plastic. The facts are summari
chart form. Four pages.—*Vacuum*
ment Div., Distillation Products Indu
Rochester 3, New York.

Wire—A folder explaining the availa
of ductile bismuth wire, its electrica
physical properties, the Hall effect, a
thermoelectric power. Twenty pages.
"Ductile Bismuth Wire—The Magic
of the Age."—*Fitzpatrick Electric S*
Co., Muskegon, Michigan.

X-ray Photometer—Explains the
of operation, principal components,
operating procedure of the x-ray photo
for chemical analyses by x-ray absor
Some of the applications in the che
and petroleum industries are listed.
pages. GEC-412A.—*General Electric*
Apparatus Dept., Schenectady 5, New

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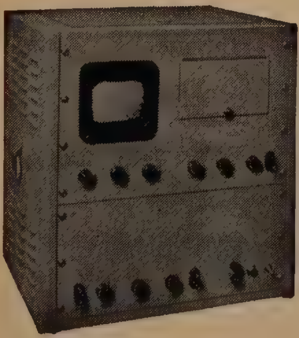

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

PLES AND APPLICATIONS OF WAVE-TRANSMISSION

C. Southworth—D. VanNostrand
ew York. 1950. 689 pp. $9.50.

book is by one of the most prominent rs in this field. A historical account of rk, together with the necessary gen- eory to provide a good understanding phenomena involved in waveguide ission, is given.

first three chapters (about 70 pages) voted to history, impedors and their ations, filters, coupled circuits, trans- n lines and wave action therein, and impedance diagrams. This is followed apter 4 by general electromagnetic heory and in Chapter 5 by waveguide . Up to this point the author has used antitative, or mathematical, approach ussion of the phenomena involved. At int and thereafter, the discussion be- qualitative, and although mathe- is not ignored, it is nevertheless linated to a verbal discussion of the mena. The material pertaining to uides and various combinations of uide components, together with a sion of source of power, is the sub- the text from page 97 to page 657.

s book is an authoritative treatment of ect which has in approximately fifteen become of primary importance in unications and radar work. As sug- by the author, however, these are e only applications or uses for such ial. It is an excellent addition to the ure of communication and microwave and should be available to all those sly involved or about to enter in this f activity. By its very organization it also prove its worth as a college text.

ELLSWORTH D. COOK

CITORS FOR INDUSTRY

. Bloomquist, C. R. Craig, R. M. gton, and R. C. Wilson (edited by . Bloomquist)—John Wiley & Sons, York. 1950. 246 pp. $4.50.

s book is timely and should be wel- by electrical engineers. The authors' ive, as stated in the preface, was to re practical application information on itors, and to facilitate in this manner se of capacitors in the industry. This have accomplished quite well.

Theory and mathematical treatment are kept at a minimum. Most information is given in tabular and curve form for ready reference. Numerous examples illustrate the use of these data. The text, with over 100 illustrations and photos, is written in simple style.

The chapter on Release of Power System Capacity (through the use of capacitors) is certainly timely and will be of special assistance to those who must increase the load on their existing power systems.

The book should be valuable to the plant engineer, utility power salesman, consulting engineer, and the industrial-power application engineer. Utility distribution engineers will also find many useful data, particularly the material on automatic control, switching, and series capacitors. The book is one of the GE-Wiley series.

L. A. UMANSKY

TRANSMISSION LINES AND NETWORKS

Walter C. Johnson—McGraw-Hill Book Co., New York. 1950. 361 pp. $5.00.

An outgrowth of class notes developed over a period of years, this book presents the basic concepts of transmission lines and four terminal networks that are of practical usefulness to both the power and communication engineer. Stressing the physical understanding of the phenomena, the material, coherently developed, begins with an emphasis on traveling waves and their reflection and refraction effects and leads to a discussion of subjects such as transmission-line charts, measurements and impedance matching of radio-frequency lines, and the design of ladder filters. Coequal with its usefulness as college text material, the book should find ready acceptance by practicing engineers who want to reaffirm some concepts or acquire some new ones; for the book is interesting and easily read.

I. B. JOHNSON

TRAVELING-WAVE TUBES

J. R. Pierce—D. VanNostrand Co., New York. 1950. 260 pp. $4.50.

John Pierce is undoubtedly one of the few persons well equipped to write this first comprehensive treatment of the theory of the TW tube amplifier. While presenting in detail the generally accepted basic theory of the TW tube, he carefully includes significant physical concepts of the operation of the tube, so important both to the tube designer and the application engineer. The material is organized in such a way that important results are easily found without searching through involved analyses. This book is necessary reading for those concerned with the development and application of the traveling-wave tube.

STANLEY E. WEBBER

ELECTROMAGNETIC THEORY

Oliver Heaviside—Dover Publications, New York. 1950. xxx+386 pp. (9 x 12 in.) $7.50.

At the centennial of his birth (1950) Heaviside was already considered a classic. No better proof of that can be offered than this giant-size small-type rendition of his Electromagnetic Theory. And to mark him truly a classic, many consider his works already old-fashioned.

At the time of Heaviside's productive period, Maxwell's field equations had no competitors to distract the attention toward more abstract and more promising fields of research. Heaviside built for Maxwell's ideas an elaborate structure with many ramifications and few omissions. In this volume are discovered many unexpected basic relations and an interdependence of concepts not to be found in more modern treatises on the application of Maxwell's equations to circuit and field problems. Unquestionably Heaviside was the first "scientific" electrical engineer in spite of (or perhaps because of) his lack of a college degree. He was not just an electrician with a B.S. or Ph.D. degree, who accepts things as he is taught.

Heaviside's dramatic encounter with mathematicians through his Operational Calculus only emphasizes the chasm between the pioneers and those who like to play safe. Battered from one side by the practical but ignorant engineers and from the other by the impractical but learned mathematicians, his spirit was thoroughly dampened, eventually ground to pieces, and finally driven into hiding. A pioneer must be strong physically and emotionally to be able to withstand the jeers and refined cruelties of upholders of established intellectual concepts.

(Continued on next right-hand page)

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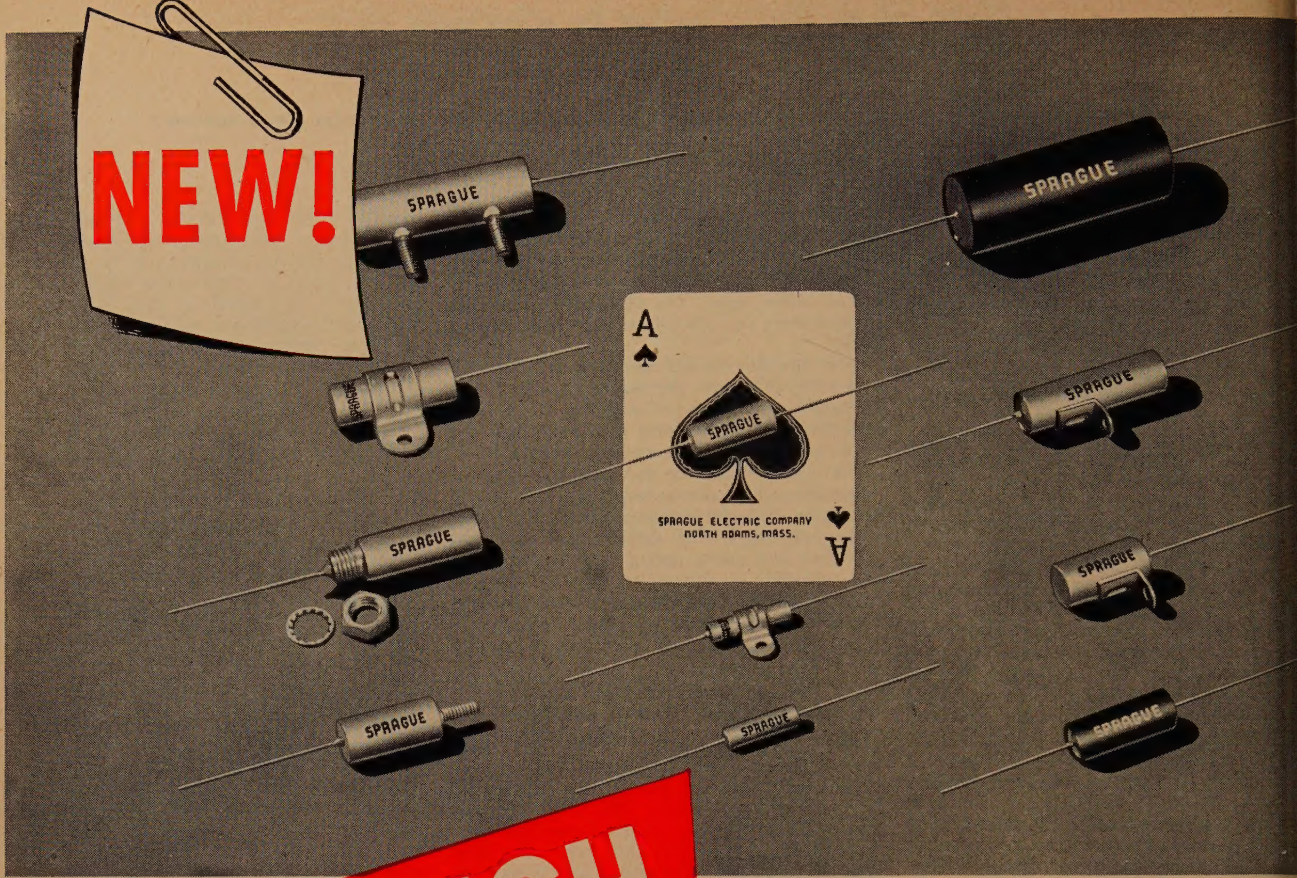

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orks of Heaviside as a pioneering
ement. And undoubtedly many of us
pplaud the pioneer who has already
away are ready and willing to tor-
he next, who is still struggling along
rny, unbeaten path.

GABRIEL KRON

NSE OF PHYSICAL SYSTEMS

D. Trimmer—John Wiley & Sons,
ork. 1950. 268 pp. $5.00.

book is an elementary exposition of
-system analysis disguised as a phil-
al treatise. The disguise, however, is
nd if one merely skips the first two
rs, one would hardly notice it. The
the book has much to recommend it
elementary textbook on control sys-
In particular; we may commend the
the so-called classical method of
g differential equations in a book of
ope, as well as the author's reason for
it (namely, that it is extensible to
degree to nonlinear cases). Dis-
d and nonlinear systems are merely
oned, and should not be considered as
the scope of the book, especially as
thor seems to be unaware that an
ous amount of work on nonlinear sys-
as already been carried on with the
machine methods of calculation.

C. CONCORDIA

STIC BEHAVIOR OF ENGINEERING RIALS AND STRUCTURES

M. Freudenthal—John Wiley &
New York. 1950. xi + 587 pp. $7.50.

present state of what might be called
nical Metallurgy is here summarized
ably. Based on a graduate course
by Professor Freudenthal, a twofold
as been set for this book: (1) the
ation of the inelastic behavior of
als, defined by the author as that set
perties which come to being beyond
stressing; and (2) to show approaches
ing engineering problems in members
ructures stressed beyond the elastic

author reviews this field first from a
ist's point of view, describing the
phenomena in terms of changes in
omic structure. He then uses this for
kground in the discussion of the gross
nical behavior. The purpose of this
gement is to show the usefulness of
ping unifying principles which can
e supplied by a theory that traces
echanical behavior back to the build-
ones of matter. Modern concepts such
equation of state are discussed with
nce to the inherent difficulties in ar-
at it. The engineer's point of view is
d by enumerating the various mathe-
al solutions of plastic-flow problems.
ad coverage is given to the behavior
ineering materials; and with the well-
d bibliography appended to each
r, the book is a valuable addition to
gineer's library.

W. L. FLEISCHMANN

TRICAL COMMUNICATION (3rd Ed.)

r L. Albert—John Wiley & Sons, New
1950. vii + 593 pp. $6.50.

the preface, the author states as his
ive the preparation of an informative
overing the entire field of electrical
unication. He has sought to bring to-
in one volume all pertinent related
ial necessary to give a general understanding of the principles, concepts, components, and systems of such communication. To keep the book within reasonable size he has, therefore, omitted detailed discussions, particularly those involving theory. The first chapter gives a brief, historical treatment of the subject and is followed by a discussion of the fundamentals of acoustics, hearing, electricity, circuits, components, devices, and systems.

The book is declarative in nature rather than analytical. Mathematics is used sparingly and such treatments are not difficult in most cases. Since copious references have been given at the end of each chapter, long mathematical derivations have been omitted and frequently the results only are stated in analytical form. The problems suggested at the end of each chapter have been chosen to aid in affixing the essential text of that chapter in the reader's mind.

ELLSWORTH D. COOK

PHYSICAL CHEMISTRY OF HIGH POLYMERIC SYSTEMS (Second Edition)

H. Mark and A. V. Tobolsky—Interscience Publishers, New York. 1950. 506 pp. $6.50.

This is a second edition of Vol. II of the series on High Polymers which originally appeared in 1940. The text has been expanded almost 50 percent and a great many examples are included of the applications of physical-chemical methods to polymer systems, taken from the literature of the past decade, which were not available earlier. The last four chapters contain material not included in the earlier edition, dealing with

(a). Mechanical Behavior of High Polymers
(b). Step-reaction Polymerization
(c). Chain-reaction Polymerization
(d). Degradation of High Polymers.

The sections dealing with the thermodynamic and kinematic behavior of polymers and those on polymerization mechanisms and degradation reflect the intensive studies carried out during the past decade.

The book is recommended to all chemists interested in these fields of research.

A. L. MARSHALL

THE PHILOSOPHY OF MATHEMATICS

Edward A. Maziarz—Philosophical Library, New York. 1950. 286 pp. $4.00.

This book presents a historical review of the relation between mathematics and philosophy. It criticizes Descartes' methods of deductive reasoning, and especially his statement that he found himself forced to doubt anything that could be subject to doubt. The author seems to feel that metaphysics and faith can provide truths, and that we should not look to scientists alone for knowledge.

P. L. ALGER

ELECTRICAL INSTALLATION WORK

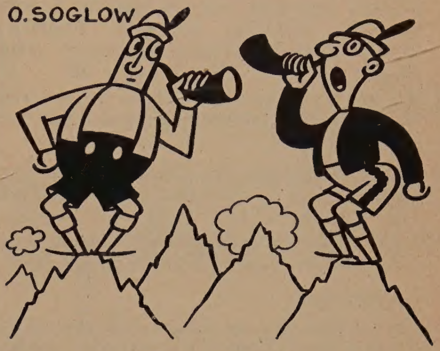
T. G. Francis—Longmans, Green & Co., New York. 1950. xv+232 pp. $2.50.

Written for the British workman about British practices and materials used in the wiring of buildings and homes, this book has no practical value generally for the American workman. It is, however, an excellent reference book for those Americans who need a general picture of British wiring materials and their application. Some theoretical treatment is given on illumination, heating, and testing, which seems rather out of place in a book which also goes into some detail in doorbell circuits, or vice versa.

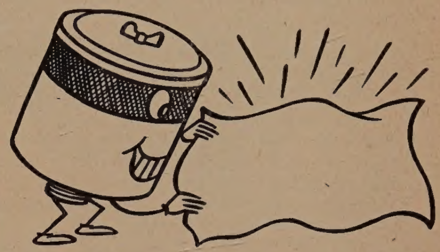
Mr. Francis has used a considerable number of well-selected illustrations.

H. H. WATSON

AIR-MAZING FACTS



WHY MOUNTAINEERS ARE DEAFER: It's harder to hear on a mountain top than it is in the valley below. That's because sound waves do not travel as readily through the thinner air found at high altitudes.



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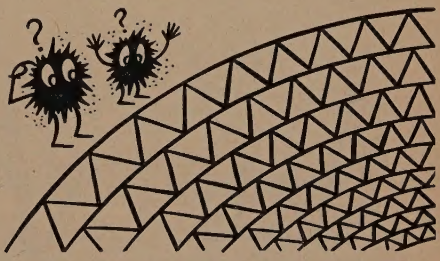

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GREASE FILTERS

LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

AIRPLANES—CONTROL EQUIPMENT

Design Method for Automatic Longitudinal Control Systems. Frederick Stevens and K. Martin Stevenson. *Aero. Engng. Rev.*, Jan. 1951; v. 10, p. 18.

Presents a new approach to the problem of designing intercoupled multiloop control systems.

Pneumatics Powers New Plane Systems. George L. Christian. *Aviation Week*, Jan. 1, 1951; v. 54, p. 28.

Describes the development of pneumatics for actuating aircraft auxiliary systems.

CATHODES

Deterioration of Oxide-coated Cathodes Under Low Duty-factor Operation. J. F. Waymouth, Jr. *Jour. App. Physics*, Jan. 1951; v. 22, p. 80.

The behavior of oxide cathodes coated on a nickel alloy containing about 0.1 percent silicon has been investigated under 100 percent and zero duty-factor operation.

Oxide-cathode Base-metal Studies. Ralph Forman and Glenn F. Rouse. *Nat. Bur. Stds. Jour. Res.*, Jan. 1951; v. 46, p. 30 (RP No. 2171).

A method for comparing the properties of two oxide cathodes—one with a high-purity-nickel base and the other with a nickel base containing a small percentage of magnesium—is discussed.

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RADIO SHACK CORPORATION, Boston
NEWARK ELECTRIC CO., Chicago
WESTREX CORP. (Export), New York City

AX-34

ELECTROPLATING

Automatic Plating Meets Stiff Defense Production Standards. John V. Davis. *Steel*, Jan. 29, 1951; v. 128, p. 63.

Close tolerances in plate thickness, better distribution, and other quality improvements are provided by modern high-production plating equipment.

Plating Improved with Reverse-current Techniques. G. W. Slomin. *Iron Age*, Feb. 8, 1951; v. 167, p. 94.

Periodic reverse-current plating makes possible greater plating speed and smoother, finer-grained deposits.

FOUNDRY PRACTICE

Continuous Casting Process Employs a Moving Mold. D. I. Brown. *Iron Age*, Jan. 25, 1951; v. 167, p. 53.

Water-cooled steel bands traveling over drum pulleys form the mold in the latest Hazelett machine.

Theoretical Basis for the Design of Gates. Morris J. Berger and Charles Locke. *Foundry*, Feb. 1951; v. 79, p. 112.

How to predict qualitatively the behavior of liquid metal flowing from a manifold gating system of circular cross section.

GAS TURBINES

How GE Makes Turbojets. E. J. Tangerman and Anderson Ashburn. *Am. Mach.*, Feb. 5, 1951; v. 95, p. 135.

Operations in the manufacture of the J-47 turbojet are pictured and described.

Off-peak Air Storage for Peaking Gas Turbines. *Elec. Wld.*, Jan. 15, 1951; v. 135, p. 64.

Hypothetical cavern storing combustion air at 100 atmospheres, which could permit two-thirds saving per kw of gas-turbine plant of conventional coupled-compressor design.

HEAT PUMP

Heat-pump Installations for Residential Use. E. R. Ambrose. *Mech. Engng.*, Feb. 1951; v. 73, p. 115.

Operating and performance characteristics of five units in different locations using air as the heat source.

Practical Application of the Heat Pump. Alwin B. Newton. *Refrig. Engng.*, Feb. 1951; v. 59, p. 143.

Precise knowledge of heat-source conditions and careful engineering are described as the key to successful operation.

INSULATION

Polyester-glass Laminates for Motor Parts. Roger B. White. *Elec. Mfg.*, Jan. 1951; v. 47, p. 84.

Other insulating components too are economically fabricated from these new materials that combine excellent arc resistance, heat resistance, and mechanical properties.

Test Report on Revolutionary Tapes. William J. Miller. *Modern Plastics*, Jan. 1951; v. 28, p. 74.

Describes adhesive-backed, pressure-sensitive oriented polyethylene tapes and films useful in electrical and electronic work.

LUBRICATION AND LUBRICAN

How to Apply Cutting Fluids to
chining Operations. R. B. Niebusch
E. H. Strieder. *Steel*, Jan. 22, 1951; v.
p. 78.

Longer tool life, better surface fi
lower power consumption, and gr
accuracy are some of the benefits re
ing from bathing cutting zones
large volumes of clean fluid.

Molybdenum Lubricant Proves It
in Tough Tests. Alfred Sonntag. *Iron*
Feb. 8, 1951; v. 167, p. 91.

Describes the applications of molybde
disulfide.

METAL CLEANING

Abrasive Tumbling; A Precision
ishing Method. *Steel*, Feb. 5, 1951; v.
p. 81.

Volume producers are using mo
tumbling techniques advantageousl
deburr, burnish, hone, and to per
finishing operations.

Scale-removal Technique with
Stainless Steels. Lester F. Spencer.
Processing, Dec. 1950; v. 36, p. 623.

Describes methods for removal of o
formed on stainless steels by high
peratures and furnace atmospheres. S

PLASTICS

Postforming Thermosetting Lamin
Plastics. William I. Beach. *Mach.*,
1951; v. 57, p. 163.

First of a series of articles on an impr
method of forming laminated pl
sheets.

Reinforced Plastics. Richard J. Fra
Prod. Eng., Feb, 1951; v. 22, p. 85.

A comprehensive discussion of
reinforced plastics.

RADIO COMMUNICATION

1540 Miles of Radio Train Commu
tion on the Missouri Pacific. *Ry.*
Jan. 29, 1951; v. 130, p. 20.

Large-scale program made practi
from economic standpoint by ado
12-volt caboose radio power plant
reduce costs.

UHF Industrial Communications
tem. Frank B. Gunter. *Electronics,*
1950; v. 23, p. 90.

Crystal-controlled microwave tran
ter and companion double-superhe
dyne receiver operating in 940–96
band provide seven voice channel
communication, telemetering, and re
control.

WELDING

Design for Welded Connections.
Jefferson and W. J. Brooking. *Weld.*
Jan. 1951; v. 36, p. 29.

Tells what the designer should
about welded fastenings. Serial.

Submerged-melt Welding with
tiple Electrodes in Series. A. R.
and E. L. Frost. *Weld. Jour.*, Feb. 19
30, p. 103.

A new method of submerged-melt we
is described with resultant advan
for such special applications as
cladding of steels.